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STATE OF CALIFORNIA
HIGHWAY TRANSPORTATION AGENCY
DEPARTMENT OF PUBLIC WORKS
DIVISION OF HIGHWAYS

INSTRUMENTATION FOR THE APPLE CANYON CULVERT

In Cooperation with
U.S. DEPARTMENT OF COMMERCE
BUREAU OF PUBLIC ROADS

DECEMBER 1966

State of California
Department of Public Works
Division of Highways
Materials and Research Department

December 1966

19605-762500-36360

Mr. J. E. McMahon
Assistant State Highway Engineer, Bridges
California Division of Highways
Sacramento, California

Attention: Mr. J. G. Standley, Jr.

Dear Sir:

Submitted for your consideration is a report of:

INSTRUMENTATION

FOR THE

APPLE CANYON CULVERT

Instrumentation performed by . . . . Foundation and Structural Materials Sections

Under direction of . . . . E. F. Nordlin and T. W. Smith

Work supervised by . . . . J. E. Barton and W. Weber

Report prepared by . . . . W. Chow and W. Weber

Very truly yours,

JOHN L. BEATON
Materials and Research Engineer

WC:mw
Attach.

I. INTRODUCTION

The California Division of Highways is designing and building higher earth fills to span our mountainous terrain. In many of these fills it is necessary to provide a means of carrying surface waters through them. Metal culverts have been employed for this purpose in many cases. The present design formulas were developed for culverts buried in light to moderate fill heights. Concern has arisen regarding the adequacy of these culvert design formulas when used for high fills. Should new theories and design formulas be formulated for culvert actions under them? In order to gain additional information, the Bridge Department of the California Division of Highways set up a research project to gather experimental data from a twin 108 inch diameter steel structural plate pipe culvert buried underneath a high (167') earth fill. This report covers the work performed by the Materials and Research Department in instrumenting this test culvert installation and in acquiring the test data. Analysis of the test data will be made by the Bridge Department.

This research work was performed in cooperation with the U. S. Bureau of Public Roads.

The opinions, findings, and conclusions expressed in this report are those of the authors and are not necessarily those of the Bureau of Public Roads.

II. THE CULVERT

This culvert installation is located on Route 5 in Los Angeles County at Apple Canyon, approximately 8 miles south of Gorman. The installation of the culvert and fill was performed as a part of a construction contract to relocate and improve this portion of the highway. A view of the Apple Canyon site, Figure 1, is shown prior to the fill construction.

The installation is a twin galvanized steel structural plate pipe culvert; that is, two pipes installed side by side as shown in Figure 2. Figure 2A is an elevation and plan view of the installation. Both 108 inch diameter pipes were ellipsed 5% to provide a nominal major vertical axis of 113 inches and a nominal 102 inches at their minor axis. This was with no fill load on the culvert. The culvert is 1077 feet long with corrugations of 6-inch pitch and 2-inch radii.

Armco furnished the structural steel plates, Figure 3, for this culvert. Each pipe ring required six steel plates. The culvert plates were about 60" wide by 96" long. Plate gage, lineal feet per gage, and bolts per plate are tabulated on Figure 2A. Each plate weighed about 700 pounds and the plates were held together with 7/8-inch diameter ASTM A325 high strength steel bolts to form the culvert rings.

The culvert plates arrived at Apple Canyon during the second week in December 1965. Our field instrumentation installation started at that time.

III. MEASUREMENT REQUIREMENTS

The instrumentation consisted of the following:

Information Desired	Measurement Method	Figure
Culvert strains	SR-4 strain gages	4
Displacement field deformation (Chord Lengths)	Inside micrometer	5
Displacement field deformation (Chord Lengths)	Photographic method	6 & 7
Culvert longitudinal change	Outside micrometer	8
Soil pressure	Soil meters	9 & 10
Fill settlement	Settlement platform	45

Of the two, the east pipe shown on Figure 11 received the full complement of the instrumentation listed above at Test Sta. 7 + 25 and Test Sta. 10 + 00. On the same pipe at Test Sta. 7 + 90, 8 + 55, and 9 + 20, each received a soil pressure meter at the top of its culvert crown only.

On the west pipe, Figure 11, soil meters were placed at the spring line of Sta. 7 + 25 and 10 + 00.

In addition to the soil meters around the two pipes, soil meters were also placed in the fill body. This is also shown on Figure 11. These meters are numbered 1, 12 through 25, and 36 through 39.

Since Sta. 7 + 25 and Sta. 10 + 00 received identical instrumentation, a description of the test installation and data acquisition for one applies equally to the other. Although we took readings with no fill on the culverts and with the fill level with the culvert crowns, all of our reduced data, as shown on the six factor computation, were based on a "zero" with 10 feet of fill over the culvert crown. We felt that this 10 foot fill "zero" or reference point was a stable point to start our data calculations from. That is, stable from the viewpoint that the fill "preload" had stably settled the pipes into their beddings and that the bolts had "popped" and the culvert plates had "stretched" into a stable state.

To know the culvert barrel strains, displacement field deformations (change in pipe shape in its vertical plane), culvert longitudinal changes (pipe stretch), fill settlements, and soil pressures against advancing fill heights, all of these data readings were taken at specified heights of overfill. These reading heights are listed on Figure 12.

A detailed report of the instrument installation and the data acquisition follows.

IV. CULVERT STRAIN MEASUREMENTS

Our Bridge Department wanted to know the inside and outside culvert strains around the east pipe at two locations: Sta. 7 + 25 and Sta. 10 + 00. Upon completion of the fill, the culvert at Sta. 7 + 25 would be under 68 feet of fill whereas at Sta. 10 + 00 it would be under 167 feet. As previously stated, the strain changes during and after the fill was completed were desired.

Culvert strains were measured with Baldwin FABX-50-350 SR-4 strain gages shown on Figure 4. This is a cross strain gage; that is, two strain gages were mounted on a common bakelite carrier in the same plane but at 90^{o} to each other. These strain gages will sense localized bi-axial culvert strains in the axial direction of the culvert and also circumferential strains around it. This particular gage was selected because of its good long-time stability and inherent moisture resisting properties.

The strain-gaged locations are shown on Figure 13 and are identical for Stas. 7 + 25 and 10 + 00. Their numbering system is also indicated. Basically the culvert was instrumented every 45^{o} completely around the barrel. We departed from this slightly at the culvert horizontal spring line because the bolted splice was in that location. Therefore we straddled the bolt line with a gaged location 12" on each side of it. The bolt lines are located a nominal 12" from each strain-gaged location.

Notice from Figure 13 that a circular line of gages was placed completely around a corrugation crown and next to it in a similar fashion around the valley corrugation.

We gaged each location back-to-back. That is, a strain gage attached to the outside of the culvert, Figure 14, was matched by a gage attached to the same location inside of the culvert and in the same orientation. Obviously, a pair of back-to-back gages would have one cross gage in the corrugation crown while the other would be in the corrugation valley or vice versa. Each of the two test stations had 40 cross gages for a total of 80 strain gage circuits.

Application of the strain gages to the culvert plates, Figure 15, was carried out at the culvert site during December 1965. The usual methods were used to apply them except these were applied under unusual weather conditions. We applied gages to the two bottom invert culvert pieces while it was snowing. Figure 16 shows one of the inverts under a snow protective tent during its gaging operation. Figure 17 is a view of the culvert area with snow on the ground.

Besides our usual method of applying epoxy waterproofing protection over the top of each gage, Figure 18, we also tack-welded a steel cover plate, Figure 19, over each of the gaged areas. The lead out cables from each strain gage were fed into a flexible metal conduit and then routed to the reading stations inside of the culvert pipe. Figure 20 is a view of 3 completed strain-gaged locations with their protective steel plates and flexible conduits routed into the culvert interior. All strain-gaged installations both inside and outside of the culvert were protected in a similar fashion.

Because of the cold weather we used large quantities of heat to set and cure the gaged installations. Figure 21 is a view of the 7 butane gas tanks used to supply the fuel for the heater heads.

As set forth in the Bridge Department test program, strain gage readings were to be taken as the fill construction progressed from 0, 10, 20, 30, 40, 50, 60, 70, 90, 110, 130 feet and to the top of the fill. Timing of the data acquisition did not coincide exactly with the above plan. Actual data acquisition was taken at fill heights as listed in Figure 12.

The actual strain gage data acquisition presented no special problems. All of the strain gage leads, whether inside or outside of the barrel, at each of the test stations, terminated in 3 of the 4 Amphenol sockets, Figure 22, located at each station inside of the culvert. Soil pressure meter cables terminated in the 4th socket.

To read all of the strain gages, a mating Amphenol plug was successively plugged into each of the three sockets. These sockets and plugs had special gold plated contacts to minimize contact problems and were very electrically stable. The other end of the plug terminated in a high quality Leeds & Northrup switch, Figure 23, which fed into a Budd strain gage indicator, shown to the left of the switch.

A set of strain gage data for each fill height totaled 160 readings at the two stations. These data were written directly at the test stations onto a 6 factor field sheet, an example of which is shown on Figure 24. This is one of the 21 sheets necessary to record all of the culvert instrumentation data at a given reading or fill height. After completion of all of the field data acquisition onto the 21 sheets, they were returned to Sacramento for their computer computations. The completed computations for one of these sheets (Figure 24) are shown on Figure 25. All of the information appearing on the six-factor field sheet example also appears on the computation page example. This example, page 1 of the 21 pages of batch 10, was part of the data which was taken on May 5, 1966, when the fill elevation at Sta. 7 + 25 was at 2703 feet, the fill height over the culvert crown was 67.9 feet, and the culvert air temperature was 61° F. Under the "DESCRIPTION" column are 4 subcolumns; "GAGE", "MEG", "IND.", and "TIME". Strain gage circuit numbers were entered under the "GAGE" subcolumn; i.e., #111 through #128. Under the "MEG" subcolumn were entered the corresponding strain gages leakage resistance to ground only if its value was below 1000 megohms. Since no entry was made, this indicates that all of these gages were above this value and were functioning properly. If other than a Budd strain gage indicator "IND." was used to read these gages, it would be entered under "IND." subcolumn. No entry under "IND." means that the Budd indicator was used throughout. The starting time of the data acquisition was recorded under the "TIME" subcolumn; in this case 1900. Under the "READING" column were the actual strain data for each of the particular strain gage at this fill height. The numbers under the "ZERO" column were the zero reference for each particular gage. As previously explained, this zero reference was with 10 feet of fill over the culvert crown. The actual change in strain, between 10 feet and 67.9 feet over the culvert crown, was computed and entered under the "MICRO-INCHES" column. For example, gage #111 went into 20 micro-inches of compression with 67.9 feet of fill over the culvert. Similarly gage #114 went into 170 micro-inches of tension with the abovementioned fill height.

The strain gage itself has an inherent accuracy of $\pm$ 1%, and the Budd indicator is readable to $\pm$ 5 micro-inches. Therefore, the over-all accuracy of any strain gage reading was $\pm$ 1% of its reading plus the readability ($\pm$ 5 micro-inches) of the Budd indicator.

Although the strain gages were applied during rain, snow, and freezing weather, only two strain gages did not meet our insulation resistance test; i.e., less than 1000 megohms to ground. These two gages, #119 and #469, showed respectively 0 and 100 megohms to ground. This occurred on July 19, 1966, for Batch 11 after the top of fill had been reached. Data from these two gages should be interpreted with caution from that date on.

It was indeed pleasing to note that of the 160 strain gaged circuits only the two noted above presented questionable data, and this happened after completion of the fill and eight months after initial installation.

V. CULVERT DISPLACEMENT FIELD DEFORMATIONS

Culvert pipe diameter deformations were of prime interest to our Bridge Department. The pipe shape was elliptical prior to fill construction so that great interest was shown as to how much the culvert would deform or become circular in shape under fill loading. The culvert interior was not strutted. As mentioned previously, the nominal vertical major axis was 113 inches and the horizontal minor axis was 102 inches with no fill on top of the culvert.

We used two measurement methods to determine the changes in pipe diameter, namely (1) the inside micrometer method and (2) the photographic method.

For the inside micrometer method, at Sta. 7 + 25 and Sta. 10 + 00, 3/4-inch diameter stainless steel balls were welded at every 1/8 point around the inside periphery of the pipe. At each station the steel balls were all mounted on the same vertical plane and naturally on the same corrugation crown. This is shown on Figure 7. At each fill height and at both stations we measured 14 chord lengths between the steel balls as shown on Figure 32. Using a Starrett #121C tubular inside micrometer, Figure 5, we were able to repeat to within ± 0.003" for each chord measurement with the same or different operators. The Starrett 121C is graduated in 0.001" steps.

Again, as previously explained for the strain gages, the inside micrometer chord length measurements were written directly onto a 6 factor field sheet. An example of this is shown on Figure 26. Again these field written data were submitted into the Highways' computer in Sacramento. Computed results for the field sheet (Figure 26) are shown in Figure 27 which were the chord length changes in inches vs. the fill height. For example, the vertical chord #14 shortened 1.865 inches with the fill height of 67.9 feet. As previously explained, the reference zero of 112.075 inches was with 10 feet of fill over the culvert crown.

The photographic method was the second method used to measure culvert displacement field deformations. We felt that the photographic method would provide chord lengths measurement accuracies to ± 0.003 inches. It would also serve as a redundant system in case the other system did not work and also as a cross check between the two measurement methods. It also provided a permanent photographic record of the test stations at their various fill heights.

In essence we took photographs, Figure 7, of the 8 steel balls at the two test stations at their various fill heights with an aerial camera. The photographs were later developed in the laboratory and the chord lengths, Figure 32, between the balls were measured on a Gaertner comparator, Figure 28. The comparator was readable to 1 micron or 0.000039 inches.

Obviously for this method to attain the desired accuracy, the camera must be relocated precisely at the same distance from the test station each time. Also, each time the film must be in the same plane; that is, no degree of pitch, roll or yaw could be tolerated.

The camera used, Figure 29, was a surplus (built in 1954) Gordon aircraft reconnaissance Type K37 camera in which we had replaced its original lens with a Kodak commercial Ektar f6.3 12-inch RA106 lens. This refocused the camera to 18 feet. Photographs were taken on 8" x 10" TRi-X ASA 400 0.090-inches thick glass plates. The camera and its associated equipment were moved from one test station to the other and resetup for each photograph.

The following is a description of the photographic setup which is identical for both test stations. Refer to Figure 30.

1. A permanently set horizontal reference string line was strung taut across the culvert interior and a mark on the top of the camera barrel was lined up beneath it. This placed the camera film, each time, at exactly 18 feet from the test station vertical plane of balls.

2. A permanently set plumb bob string line was dropped from the top-center of the culvert crown. A mark on the front of the camera barrel was matched with this plumb line. This placed the camera film, each time, at the same transverse position in the culvert.

3. A cross level was mounted permanently on top of the camera housing. Leveling these two cross bubbles brought the film into its vertical plane.

4. A 7 power telescope finder was mounted on top of the camera barrel. It was precisely aligned and attached to the longitudinal camera barrel axis. Sighting into the telescope finder we could line its vertical crosshair, by slight horizontal camera rotations, with a plumb line, Figure 31, at the test station 18 feet away. This insured that the camera was "pointing" straight down the culvert.

These 4 step adjustments from the camera position ensured that all subsequent photographs would be taken from the same location and with the photographic film always in the same plane.

At the test station, Figure 31, a plumb line was dropped from the top of the culvert, as previously mentioned. Also, a reference length bar (Figure 31) of 71.308 inches was mounted on a tubular frame. This bar was positioned exactly into the plane of the test station balls by lining it up beneath an "in-plane" string line. This reference length bar (71.308") served as a known calibration length constant on all the photographs for later chord length determinations on the Gaertner comparator.

A highly sensitive level, Figure 7, was mounted on the reference length bar and the bar was leveled. Any twisting or rotation of the culvert barrel could then be detected by measuring the relative changes of lengths between the reference bar balls and the culvert balls.

To provide a sharp ball outline on the photographs, Figure 7, they were painted each time with a machinist bluing and a white cardboard square placed in back of the balls to provide a high contrast background. We tried several different methods and the above worked out to be the best. A photoflash using a single #25B flashbulb was used to take the photograph. The photoflash bulb was tried in various locations and the best location was 9 feet in front of the camera and in the center of the culvert. This provided light rays that emanated from the flashbulb in a conical radial direction that cast shadows away from the side of the balls from which the subsequent measurements were to be taken.

We had tried mutiple combinations of flashbulbs at various locations, both in front and back of the camera, with no success. That is, the various shadows cast by the balls made it a nebulous affair in determining the true ball outline.

We also tried flashbulbs mounted in tin cans placed behind each ball. When the 8 flashbulbs flashed, the balls would be illuminated from behind instead of in front of them as previously explained. Halations around the ball edges discouraged this method.

A comparison of the chord lengths differences between the inside micrometer method and the photographic methods are shown on Figures 32 and 33. Data for this particular comparison were taken from the raw data which comprised the first eight batches of chord length measurements taken for the eleven Apple Canyon fill heights. The eight batches of chord length measurements were combined and each of the 14 chord length minimum difference, maximum difference, and average difference are tabulated.

For example, on Chord 1, Figure 32, the minimum difference (inches) between the photographic method and the inside micrometer method was 0.026". The maximum difference was 0.140", and the average difference for the eight batches of measurements for chord No. 1 was 0.070". We are certain that the mechanical extensometer can account for only 0.003" of these differences and that the inside micrometer was measuring the true chord lengths to within ± 0.003". On this basis, the large chord length differences between the micrometer and photographic methods can be attributed to the inaccuracies of the photographic method.

Another reason that leads us to the conclusion that the photographic method was inaccurate is based on Figure 34. This is a comparison of the photographic and micrometer differential change in chord lengths vs. fill heights. Note that the micrometer differential chord length changes are somewhat linear vs. fill heights. It also becomes smaller as the fill gets higher, which is reasonable and according to theory. This is not the case with the photographic differential chord length changes which are erratic and show no trend. Only chords No. 1 and 14 were used in this comparison but they are typically representative of the data from the other 12 chords.

Figure 35 is a statistical analysis of the 206 chord length measurements from the eight fill heights. Chord length differences between the photographic and micrometer methods are graphed on Figure 35 as a frequency distribution. We are confident that the extensometer measures the true chord length to within ± 0.003". On this premise the statistical analysis indicates that:

1. On the average the photographic method measures a true chord length to within ± 0.092". In other words, the photographic measurement method differs from the micrometer measurement method, on the average, by ± 0.092".

2. The photographic measurement method's standard deviation is 0.060". This means that in any future photographic measurements chances are that 68% of the measurements will be within ± 0.060" of the true chord length.

We are not sure of the reasons contributing to the differences between the two measurement methods. We list the most probably photographic causes as follows:

1. The exact outline of the balls on the photographs were somewhat nebulous. This was probably due to:

   a. Graininess of the film.

   b. Poor contrast between the balls and their background.

2. Wood film holders for the glass photographic plates were probably not sufficiently rigid. This may have caused distortion in the photographs.

3. Exact adjustments of the camera and the reference length bar may be a contributing factor due to the difficult field conditions inside of the culvert.

4. Removal of the original Aero Ektar 12" f2.5 lens and installing our Ektar 12" f6.3 lens may have created unknown errors or distortion in the camera system.

5. Our Ektar f6.3 lens was not calibrated so that its field of distortion was not known.

VI. CULVERT LONGITUDINAL LENGTH CHANGE

Did the culvert barrel, in its axial direction, elongate or shorten under advancing fill height at the two test stations? To answer these questions, one additional stainless steel ball was welded at the top, bottom, and at both sides of the spring line of the culvert barrel. All of these 4 additional steel balls were welded 12" away from the previously described chord length balls and in a parallel line with the culvert axis.

To measure the culvert length changes between these 12" spaced balls, we used a Starrett #224D-R1 outside micrometer, Figure 8. The least reading on this micrometer is 0.001". Again, as previously explained, the axial length changes were written onto a 6 factor field sheet, Figure 36, and their differential length changes were computed by our Highways' computer, shown on Figure 37.

VII. SOIL PRESSURE MEASUREMENTS

Early in the planning stages of this project, a conference was held between the Bridge Department and the Materials and Research Department to select the best available soil pressure meter for this project. From our laboratory experience, it was pointed out that the commercially available Carlson soil stress meter was not satisfactory for this project. The reason was that the 7" x 3/4" diameter strain gage housing attached to the flat side of the "pancake" disc was susceptible to being broken off by slight fill movements, both during and after embedment of the meter in the fill. No other commercially made American soil stress meter was known to us.

A Kyowa soil stress meter made in Japan was available which did not have the objectionable protruding housing. However, we also rejected this meter because of our lack of experience with it and the long delivery time that would be involved.

Therefore, the Materials and Research Department modified 42 Carlson soil meters for this project. A cross-section sketch of these modified meters is shown on Figure 10. Note that the housing protrusion is approximately 1 inch against 7 inches for the original Carlson meter. The meter "pancake" disc or blanks were especially made for us by Roy Carlson of Berkeley, California. For the transducer portion of the meter we selected a Schaevitz 033SSL lineal variable differential transformer commonly known as an LVDT transducer. We selected this electrical transducer because of its inherent longtime moisture and electrical stability.

We took special care in installing the LVDT into the Carlson housing to ensure that no moisture would seep into it. Caps of the LVDT housing were sealed with an O-ring, and the cap threads were "painted" with an epoxy cement prior to screwing it on. Connection cables were spliced onto the LVDT wires. The splice terminated in a ½" galvanized T, and the chamber of the T was completely filled with a waterproof epoxy. Thus the whole LVDT electrical system was protected against moisture. How well this job was accomplished was evidenced by only one meter, number 007, which indicated moisture leakage on July 19, 1966.

The soil meter readout instrument was a modification of a Baldwin Type K strain gage indicator. Prior to our modification of the Baldwin indicator, we searched the literature for a commercially available battery operated LVDT readout instrument and could find none. Therefore, we modified two of our Baldwin Type K indicators (shown on Figure 23). Figure 38 is a schematic diagram of the modified indicator. In all cases Baldwin indicator #1 was used for all soil meter data acquisition at the Apple Canyon Culvert.

The 42 soil pressure meters were calibrated prior to their installation into the fill. Figure 39 is a picture of the calibration setup. A vertical load was applied against the meter faces by a hydraulic jack and the vertical load was measured by a Baldwin load cell. The output of the soil meters was indicated on the Baldwin indicator, and individual calibrations were obtained for each of the 42 meters. A typical calibration is shown on Figure 40 for meter #1. In all cases 58.6 square inches was the effective area of each meter. This area was used to convert the vertical load applied into psi soil pressure.

Soil meter ranges used on this project were 100 psi and 200 psi. Both of these meters had a diaphragm deflection of approximately 0.012" at full load pressure. This was possible because the diaphragm of the 200 psi range meter was thicker than that of the 100 psi range meter.

These 42 soil meter locations and their numbering identity are shown in Figure 11. All of the 42 meter cables passed through from the outside of the culvert barrel near the two test stations into the interior of the barrel. There they terminated in the Amphenol sockets in a similar fashion as previously explained for the strain gages.

All of the portions of the soil meter cables which were in the fill body were routed through Greenfield flexible metal conduit. This was to ensure that the cables would not be cut or damaged during the fill construction or afterwards.

The meters placed around the periphery of the barrel presented no special installation problems. They were installed so that their meter faces were 6 inches from the culvert periphery and tangent to it. Figure 41 is a view of 5 meters, 3 on top of the culvert and 2 on the ground, ready for their placement when the soil rises to the correct depth for their placement.

Meters in the fill body which were some distance above the culvert crown presented a different installation problem. Here several inches of the end of a number of vertical 1" conduit riser pipes were wedged loosely through the culvert crown. As the fill height advanced, another length of 1" pipe would be screwed onto the previous pipe end until the correct fill height had been reached. Finally, at the correct fill height for a series of soil meter installations, a metal junction box was attached to the pipe. Again, soil meters were placed into their assigned fill locations, Figure 42, and their cables fed through their Greenfield tubing, into the junction box, and passed down through the riser pipe into the culvert interior. Several meter cables were passed down through a junction box and their respective Greenfield tubings were anchored to it. This was where the problems occurred. Contractor's compaction equipment and earth moving equipment passing over the top of the junction boxes, even after several feet of fill had covered them, crushed the boxes and pinched the meter cables against the interior junction box edges and the cables were cut in two. This happened for meters #16 through #24 inclusive and meters #37, 38, and 39 (see Figure 11). We are sure of our deductions since sections of the cut cable were pulled down through the riser pipe into the culvert interior. There, upon examination, we could see evidence of the pinched and cut cable ends. Unfortunately, we could not get access to these cut cables to repair them. Consequently we have no data from these soil meters.

Of course, the riser pipes were installed about 10 feet away from the two test stations to minimize its influence on them.

Soil meter pressure data recordings were taken in a similar manner as the strain gages. Obviously soil meters #13 through #24, and #37, 38, and 39 which were embedded 16.5' above the culvert spring line could not have a reference zero of 10 feet of fill over them. Here the "zeroes" used for these meters were with no fill height over them. Data entry onto the 6 factor computation sheets, Figure 43, are similar from previous explanation and none given here. Figure 44, the computed results, are self explanatory.

The modified Baldwin soil meter indicator has a least reading of 10 units. Depending on the calibration of any particular soil meter, this represents approximately 3 psi. Therefore, the accuracy of any soil meter reading was approximately ± 3 psi.

VIII. VOLUMINOUS DATA COLLECTED

Data acquisition for one batch at a particular fill height produced this number of data points:

	Data Points
Strain gages	160
Chord lengths	28
Culvert axial lengths	8
Soil pressures (12 "lost" meters not included)	30
Total Data Points	226

To date (October 6, 1966) 12 batches of data acquisition have been completed. Data acquisition for 6, 9, 12, 15, 18, and 24 month intervals are yet to be taken.

It is obvious that the 12 batches of data produced 2712 data points. To have used arithmetic hand reduction on this voluminous data would have been a tedious time consuming task, subject to numerous human mistakes and time delay.

Hence, the 6 factor computation method was used at the onset. It produced accurate data reductions and minimized time delays from field data acquisition to final reduced data.

IX. SETTLEMENT PLATFORMS

Standard fluid level type settlement platforms using three foot to ten foot risers were installed (Figure 45) by the special studies unit of the Foundation Section.

Each unit was equipped with independent air, water and drain lines, with the air and water lines encased in 3/4" flexible metal conduit. A trench was cut for the placement of the conduit and was backfilled with select material (Figures 46 - 48). Settlement platform locations for stations 10 + 00 and 7 + 24 are given on Figures 49 and 50.

The settlement data from these installations are being used to establish the "plane of equal settlement" or the level in the embankment at which settlement over the culvert is equal to that outside the culvert limits.

Sample settlement readings are shown on Figure 51 along with a sample curve plot on Figure 52.

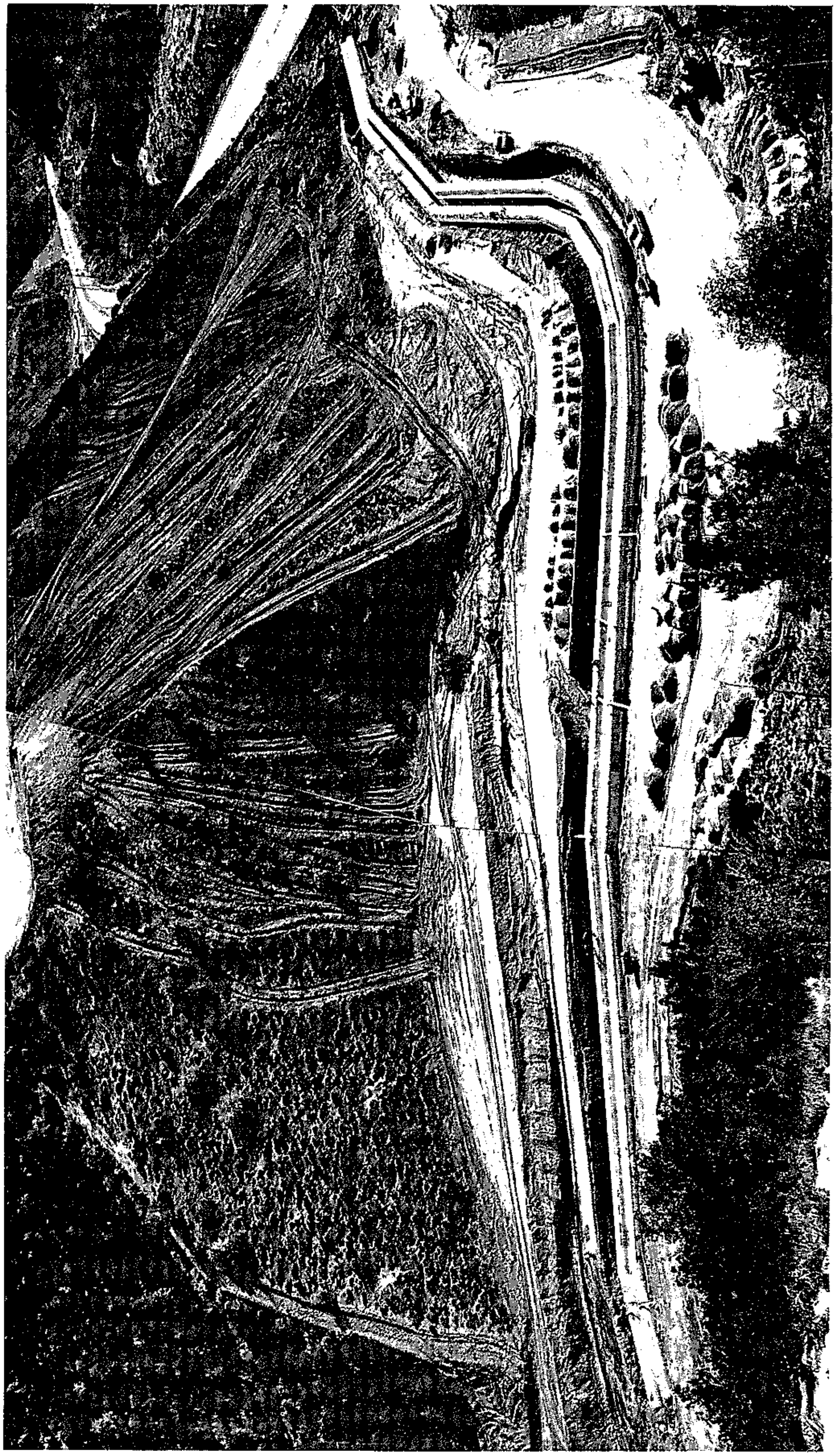
The instrumentation design layout prescribed that eleven fluid type settlement platforms would be placed in four layers at culvert Stations 7 + 25 and 10 + 00.

The first two levels of settlement platforms at these stations were inadvertently installed in a line normal to the culvert instead of in line parallel to freeway centerline as was intended.

Since Station 7 + 25 on the culvert was under the fill slope, placement of the settlement platforms on reference lines normal to the culvert positioned them beneath less than the maximum height of fill. For this reason it was necessary to increase the number of platforms at this station to eighteen. Seven of these platforms were referenced to a line parallel to freeway centerline.

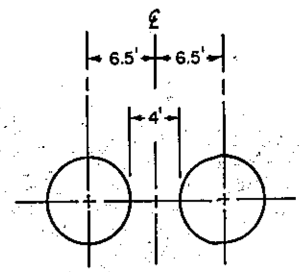
Settlement platforms numbers 63 through 68 were rendered inoperative after 94 days of operation, when the lines were temporarily disconnected to allow the placement of a drainage pipe which crossed in the path of the settlement lines.

FIGURE 1



APPLE CANYON CULVERT SITE PRIOR TO FILL CONSTRUCTION

INSTALLATION AT APPLE CANYON OF 108" x 1077' TWIN PIPE CULVERT

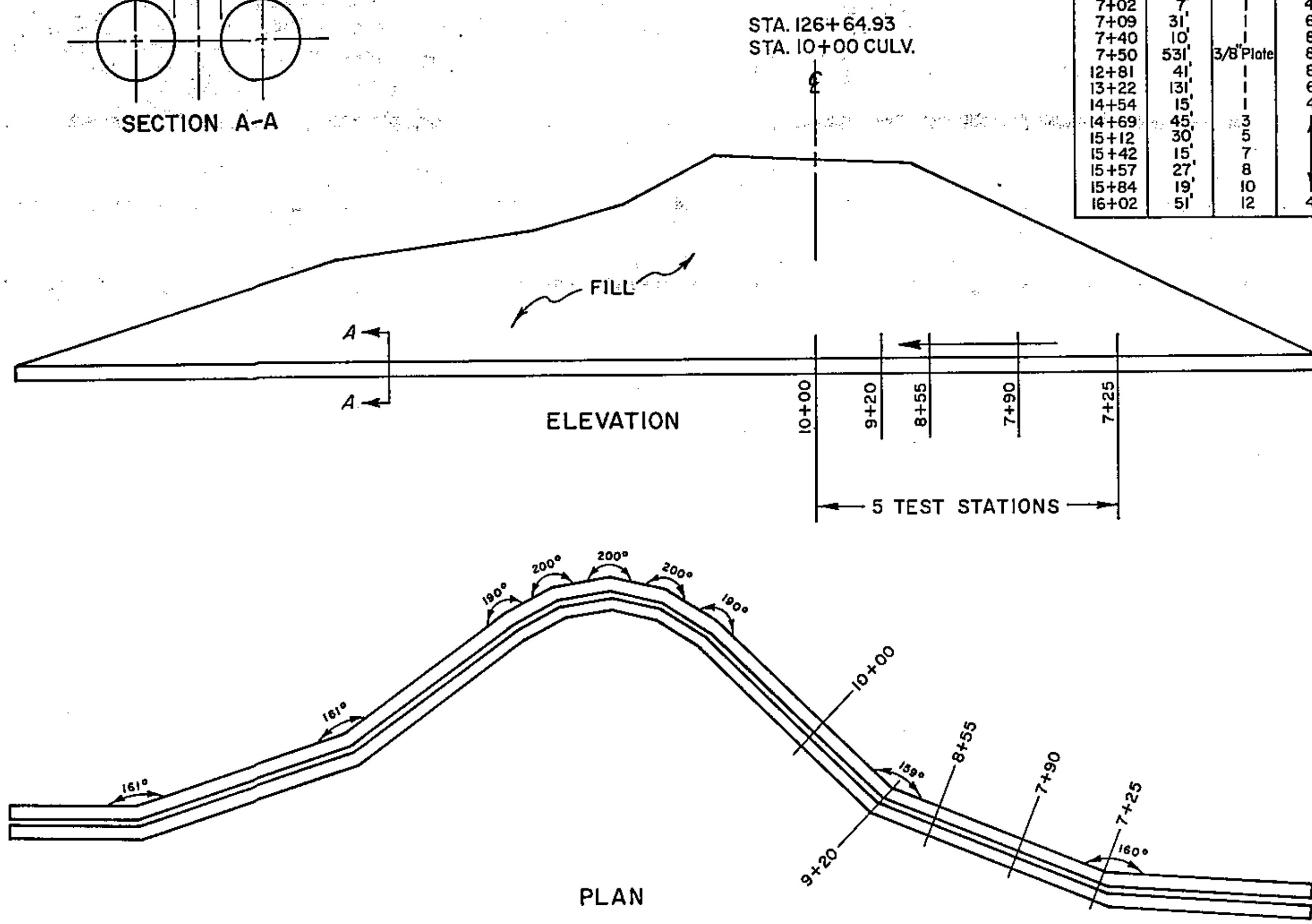


SECTION A-A

NO SCALE

PLATE GAGE TRANSITION TABLE

STATION	L.F.	GAGE	BOLTS
5+79	41'	12	4
6+20	17'	10	
6+36	18'	8	
6+54	8'	7	
6+62	14'	5	
6+77	25'	3	
7+02	7'	—	4
7+09	31'	—	6
7+40	10'	—	8
7+50	531'	3/8" Plate	8
12+81	41'	—	8
13+22	131'	—	6
14+54	15'	—	4
14+69	45'	3	
15+12	30'	5	
15+42	15'	7	
15+57	27'	8	
15+84	19'	10	
16+02	51'	12	4



ELEVATION

PLAN

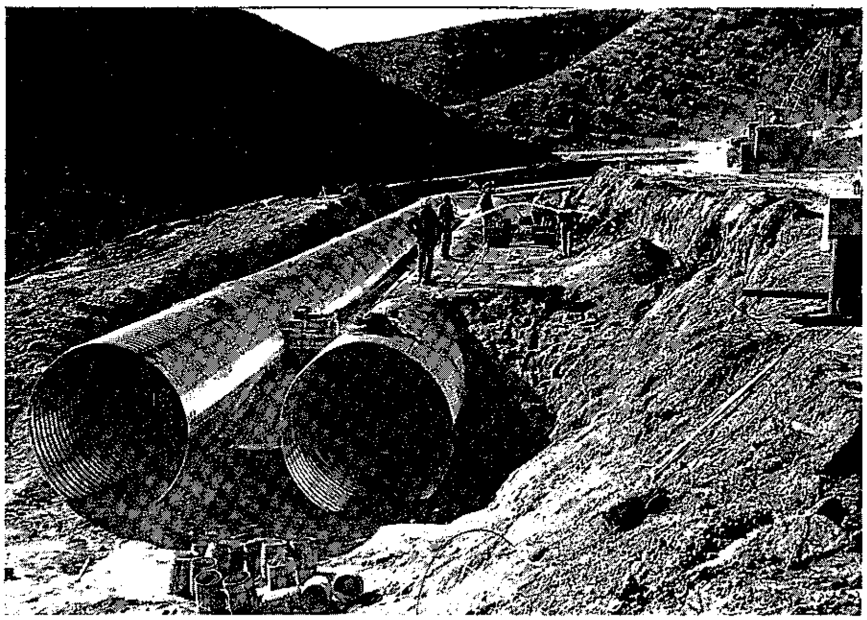


FIGURE 2

ELEVATION AND PLAN VIEWS OF APPLE CANYON INSTALLATION

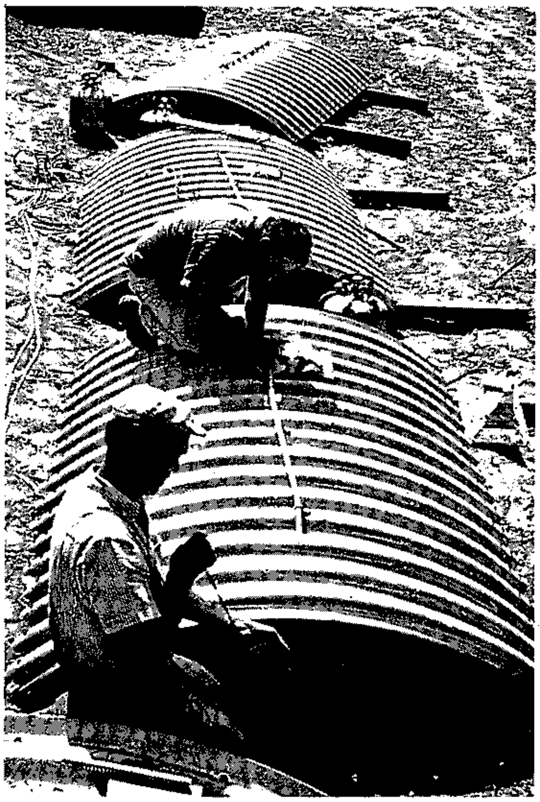
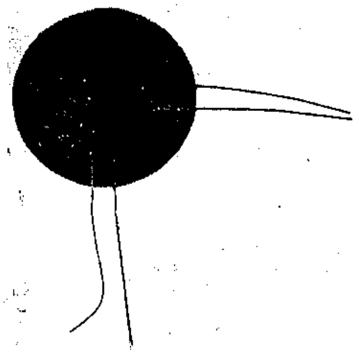


FIGURE 3

CULVERT MULTI-PLATES

FIGURE 4

STRAIN GAGES



2 gage cross

BALDWIN SR-4 FABX - 50 - 350 STRAIN GAGE

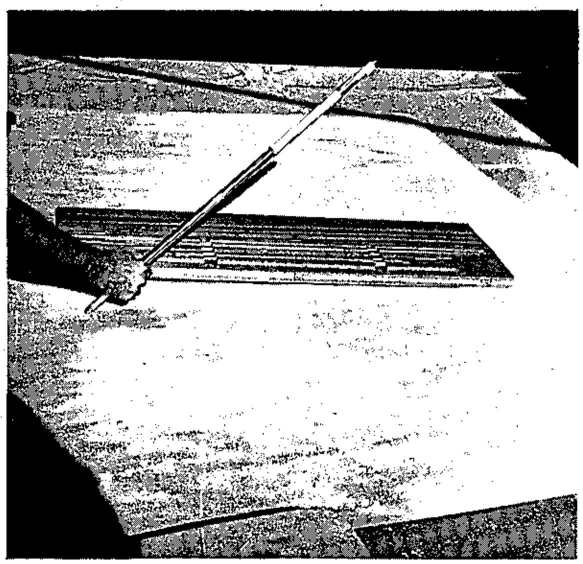
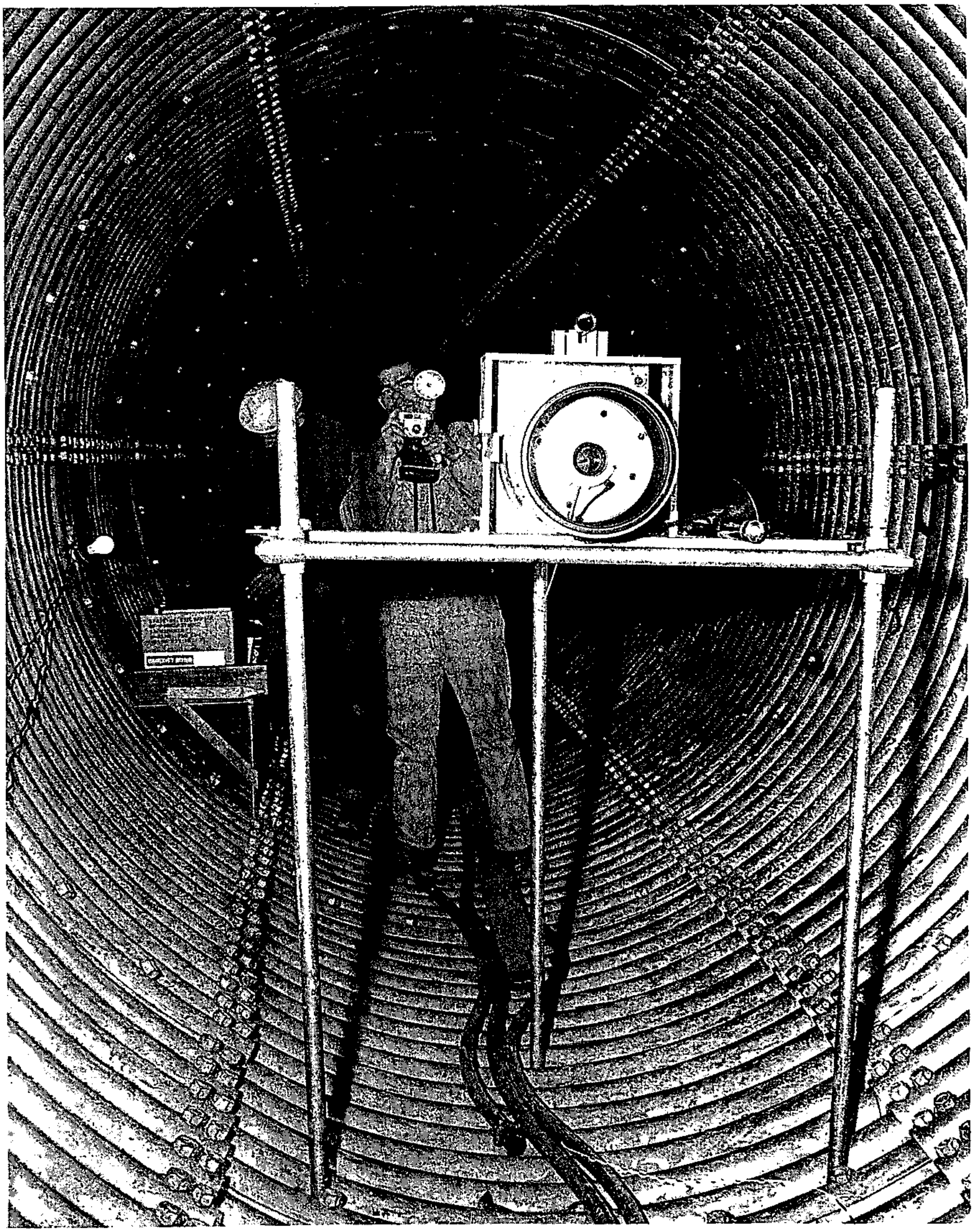


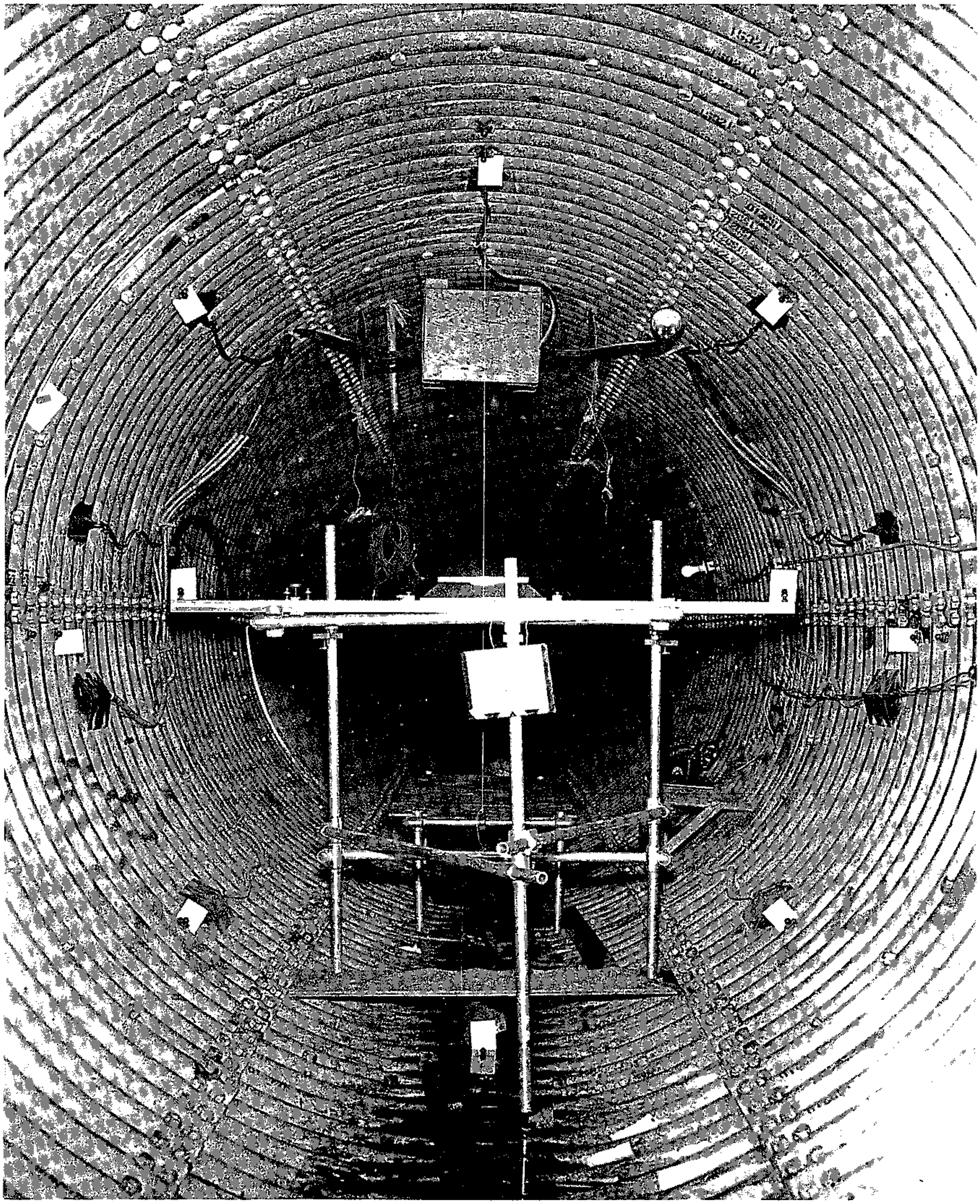
FIGURE 5

INSIDE MICROMETER

FIGURE 6



CAMERA MOUNTED ON TUBULAR FRAME FOR TAKING DISPLACEMENT FIELD DEFORMATION PHOTOGRAPHS



CAMERA VIEW OF TEST STA. 7 + 25 WITH ITS 8 STEEL BALLS
FOR DISPLACEMENT FIELD DEFORMATION MEASUREMENTS
AND THE REFERENCE LENGTH BAR MOUNTED ON ITS TUBULAR FRAME.

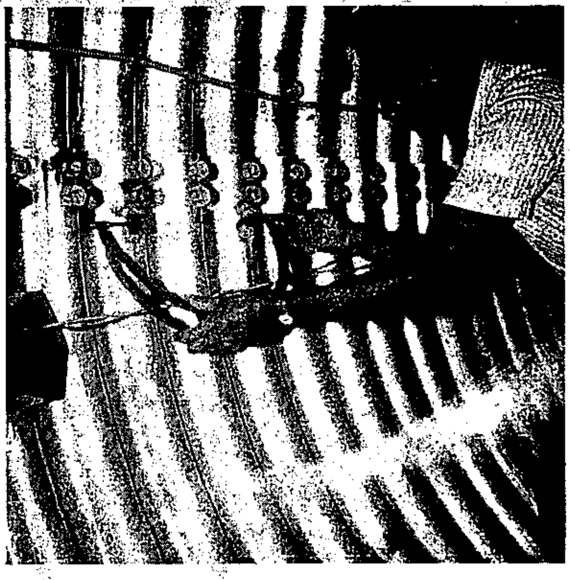


FIGURE 8
OUTSIDE MICROMETER

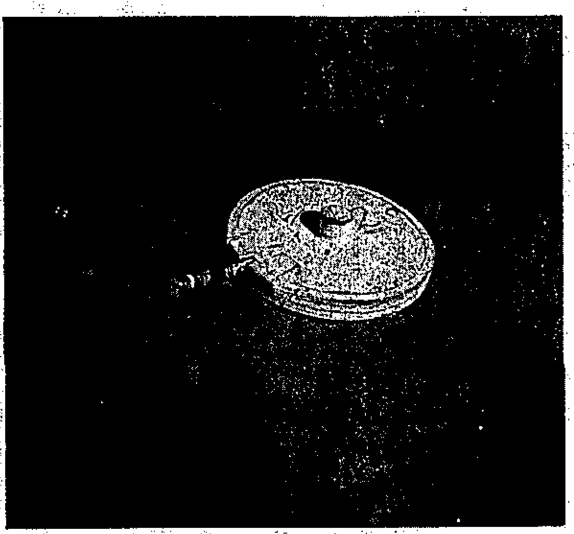
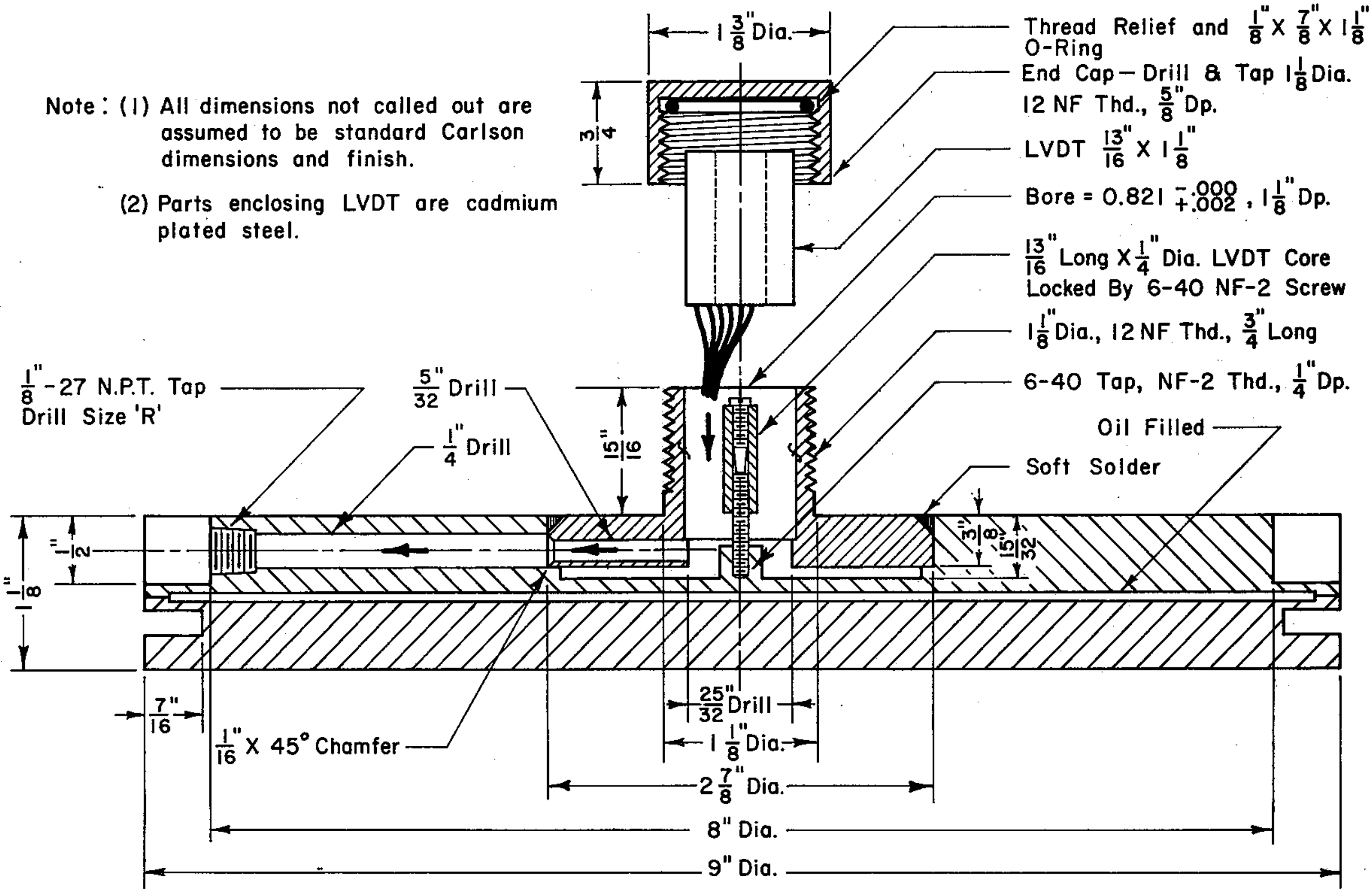


FIGURE 9
SOIL PRESSURE METER

MODIFIED CARLSON STRESS METER WITH LVDT TRANSDUCER



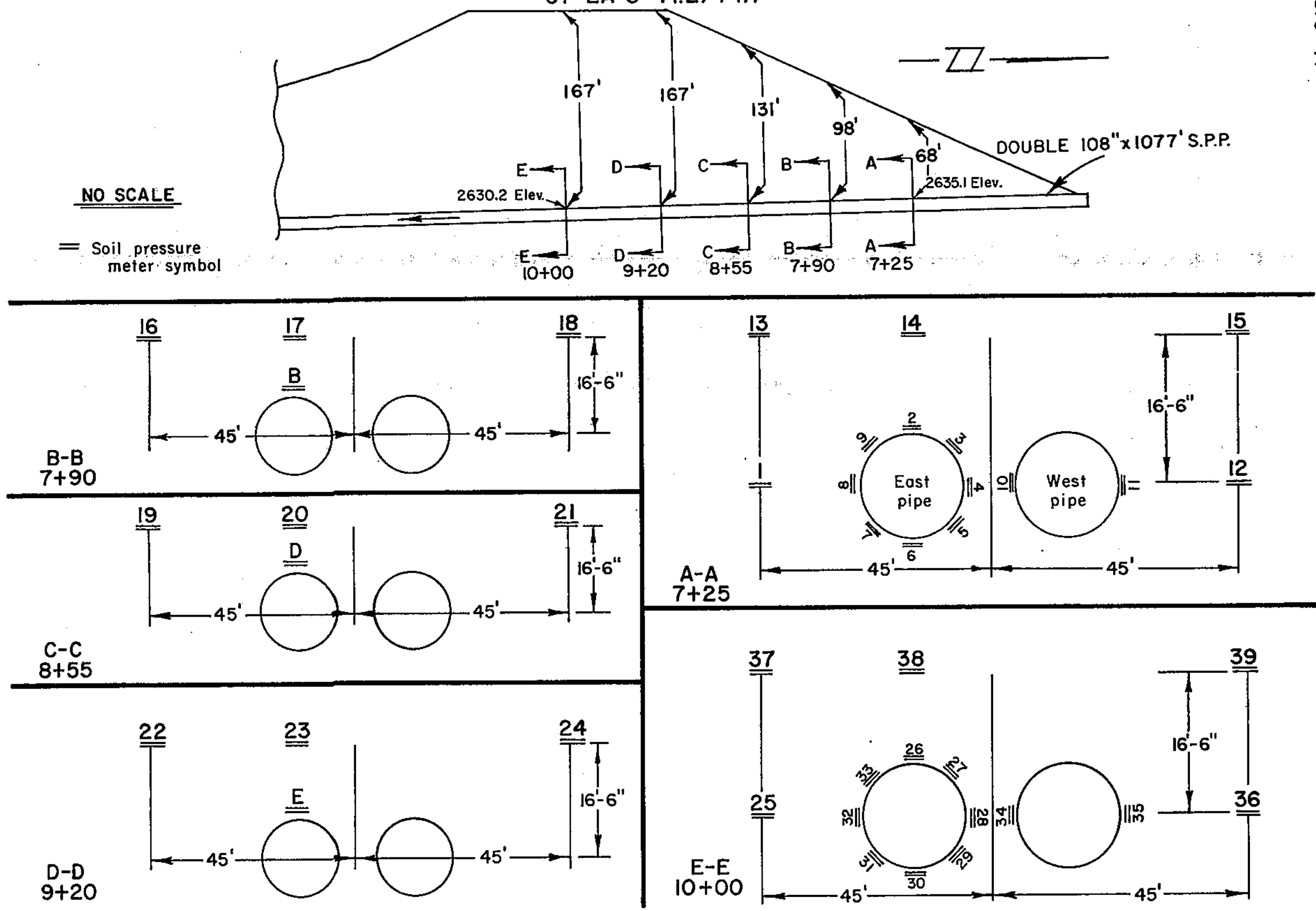
Note: (1) All dimensions not called out are assumed to be standard Carlson dimensions and finish.

(2) Parts enclosing LVDT are cadmium plated steel.

Figure 11

APPLE CANYON SOIL PRESSURE METER IDENTIFICATION

07-LA-5-71.2/74.7



APPLE CANYON

Data Acquisition vs. Fill Heights

Date	Batch	7 + 25		10 + 00	
		Elevation	Fill Over Crown	Elevation	Fill Over Crown
		2635.1	0	2630.2	0
	*	2645	10.0	2630	10.0
3-9-66	1	2656	20.9	2656	25.8
3-16-66	2	2658	22.9	2664	33.8
3-28-66	3	2674	38.9	2674	43.8
4-4-66	4	2687	51.9	2685	54.8
4-8-66	5	2703	67.9	2703	72.8
4-12-66	6	2703	67.9	2710	79.8
4-15-66	7	2703	67.9	2730	99.8
4-22-66	8	2703	67.9	2752	121.8
4-29-66	9	2703	67.9	2775	144.8
5-5-66	10	2703	67.9	2793	162.8
7-19-66**	11	2703	67.9	2790	159.8
10-6-66**	12	2703	67.9	2790	159.8

* Reference level of fill.

** No photos taken.

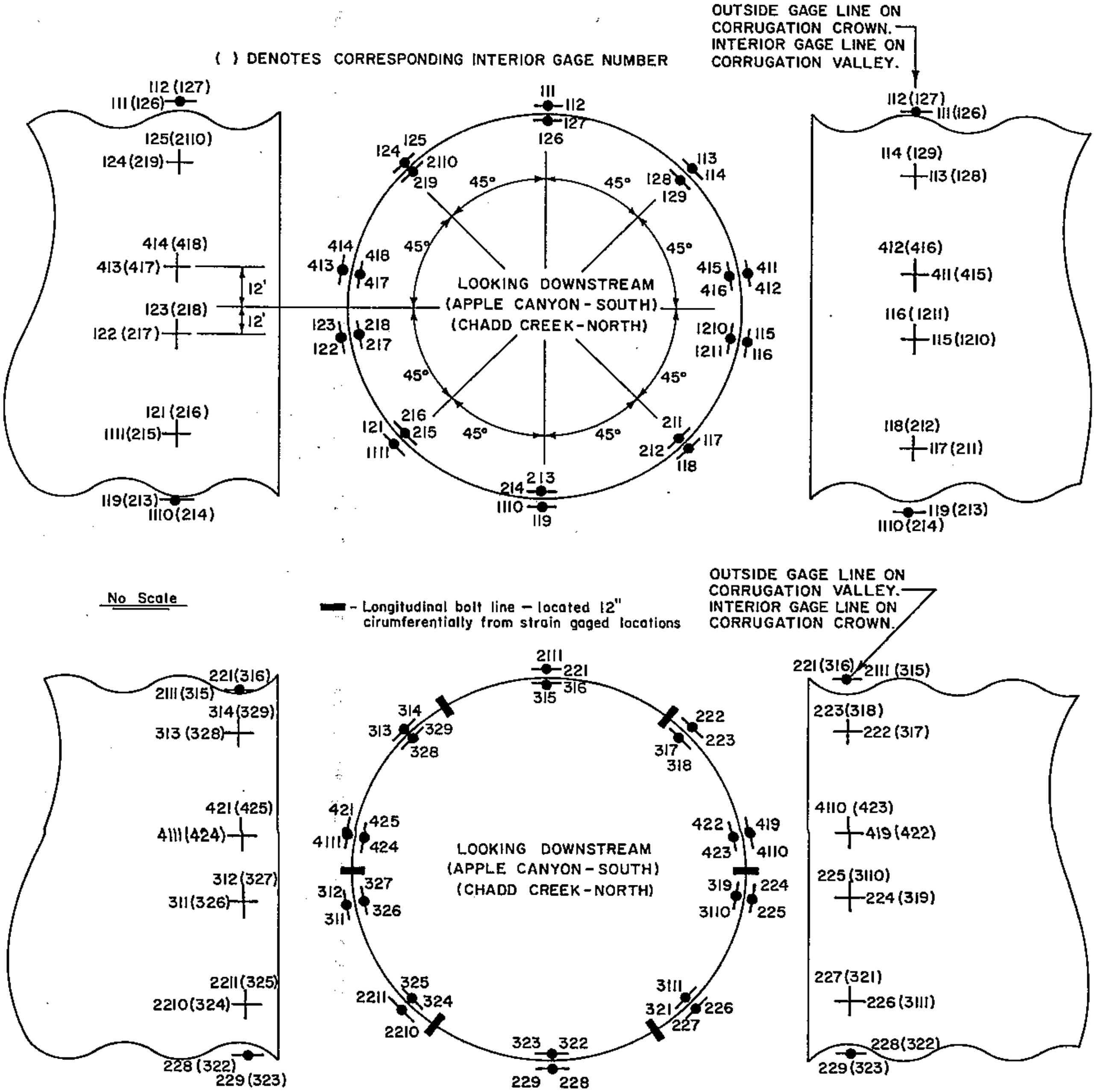
Top of fill 167' over crown of pipe.

Figure 13

STRAIN GAGE NUMBER SYSTEM (identical at each sta.) FOR CHADD CREEK AND APPLE CANYON CULVERTS

GAGE STATIONS

CHADD CREEK	0-96, 0+44, 1+00
APPLE CANYON	7+25, 10+00



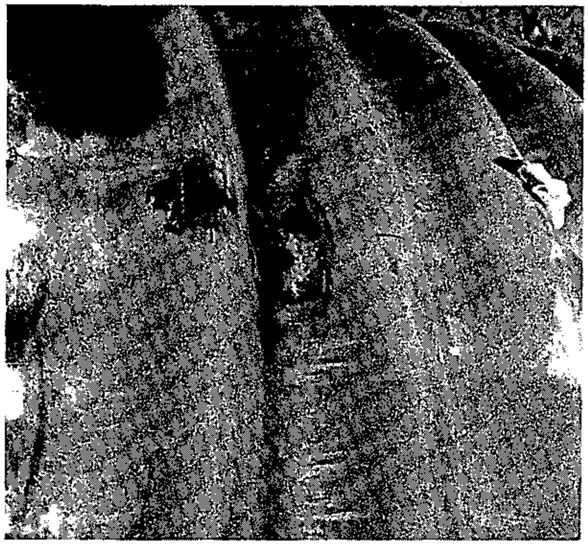


FIGURE 14
STRAIN GAGES ON CROWN
AND VALLEY OF CORRUGATIONS

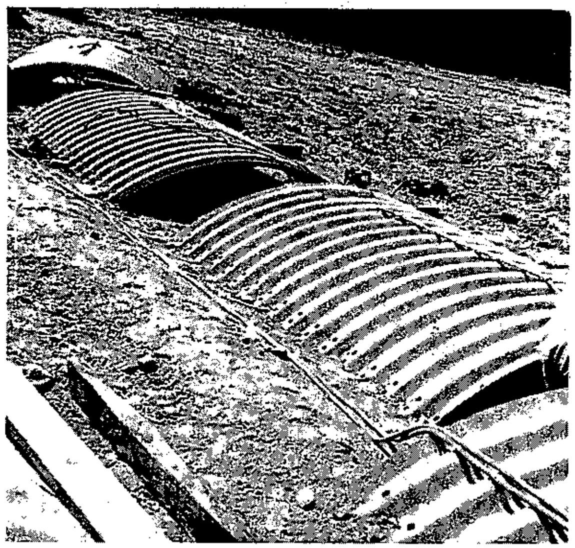


FIGURE 15
CULVERT PLATES

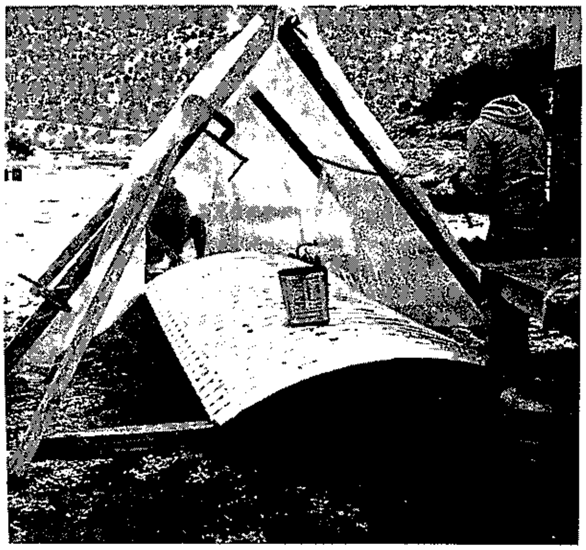


FIGURE 16
STRAIN GAGE APPLICATION
UNDER PROTECTIVE SNOW TENT

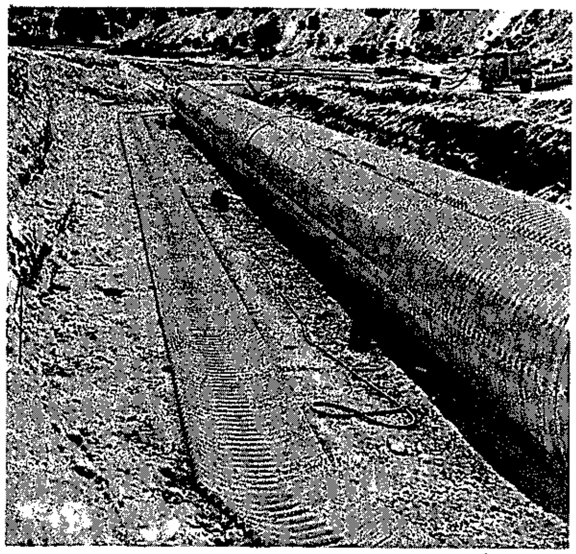


FIGURE 17
WINTER SCENE AT THE JOBSITE

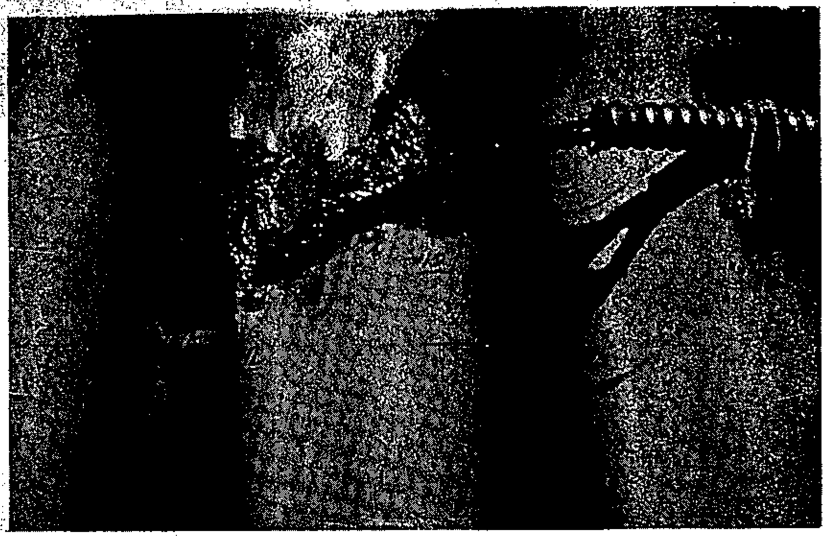


FIGURE 18

EPOXY WATERPROOFING COVERING STRAIN GAGES

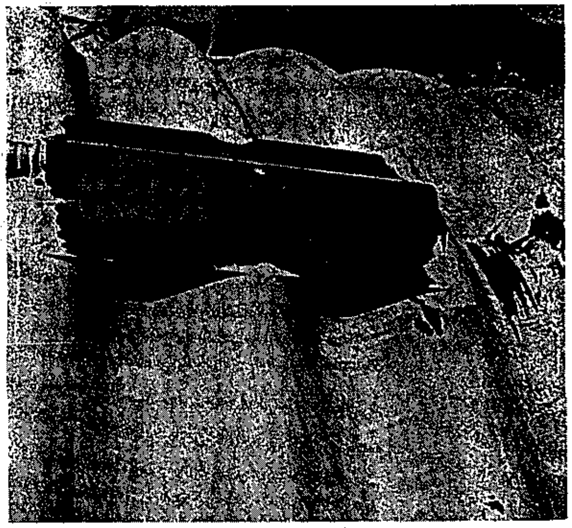


FIGURE 19

PROTECTIVE STEEL PLATE COVER
OVER A STRAIN GAGED AREA

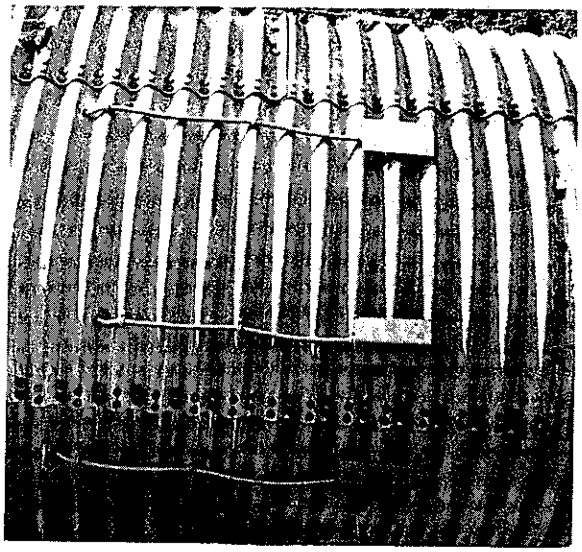


FIGURE 20
THREE COMPLETED STRAIN GAGED INSTALLATION

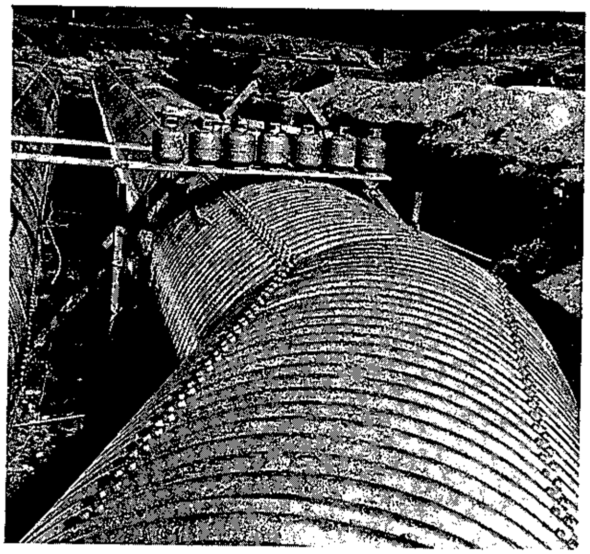


FIGURE 21
BUTANE GAS HEATER TANKS FOR CURING STRAIN GAGE INSTALLATIONS

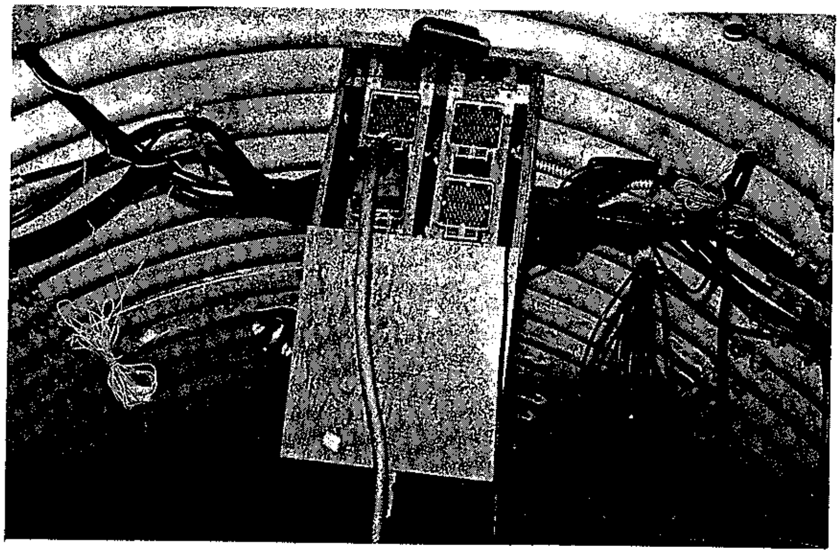


FIGURE 22
STRAIN GAGE AND SOIL METER CABLES TERMINATED IN THE ABOVE FOUR SOCKETS. A PLUG IS SHOWN CONNECTED INTO A SOCKET.

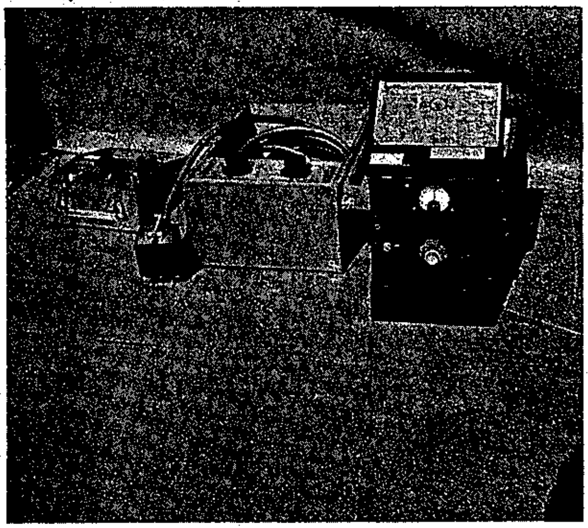


FIGURE 23

DATA ACQUISITION INSTRUMENTS

Left - Budd Strain Gage Indicator

Center - L & N Switch with Plug

Right - Modified Baldwin LVDT Indicator

Figure 24

STATE OF CALIFORNIA — HIGHWAY TRANSPORTATION AGENCY
DIVISION OF HIGHWAYS
COMPUTER SYSTEMS

6 FACTOR COMPUTATION

DIST	GROUP	BATCH
19	6	10

IN CASE OF ERROR RETURN DATA DO NOT CONTACT | CHECK

SOURCE DIST.	SOURCE UNIT	CHARGE DIST.	CHARGE UNIT	EXPENDITURE AUTHORIZATION (GEN. LED. / SUB-ACCT. / MAINT. W/O / ROUTE NO.) WORK ORDER NO.	SPECIAL DESIGNATION (USE WHEN APPLICABLE) PREFIX / BRIDGE NUMBERS / PARCEL OR CONTR. NO. / DWG. RPTS. LABR. / CDS.. ENCR. PMTS / SUB-JOB NOS. / LOCATIONS	OBJECT
19	605	19	605	762500	36360	142

LINE (6 7 8)	TYPE (9)	DESCRIPTION (10–27)	STORE DESC (28)	±	[(A (29–35)	* (36)	±	B) (37–43)	* (44)	±	C] (45–51)	* (52)	±	[(D (53–59)	* (60)	±	E) (61–67)	* (68)	±	F] (69–75)	STORE RESULT (76 77)
001	D	← 20 →			MATERIALS			AND RESEARCH			DEPARTMENT										
002	D	← 31 →						GAGE REDUCTIØN													
003	D	← 32 →						APPLE CANYØN													
004	D	← 32 →						DATE			5 MAY, 1966										
005	D	← 25 →			FILL			ELEVATION			2703										
006	D	← 26 →			CULVERT			AIR			TEMP. 61°F										
007	D	← 20 →			REMARKS			67.9 FT.			FILL ØVER			CRØWN							
008	D	← 20 →			STRAIN GAGES																
009	D	← 20 →			STATION			7+25													
010	H	4 MICRO-INCHES			READING			ZERØ													
011	D	GAGE MEG IND. TIME																			
012		1.1.1 1900		-	0835	-	-	0815													
013		1.1.2		-	0950	-	-	0345													
014		1.1.3			0250	-		0675													
015		1.1.4			0730	-		0560													
016		1.1.5			0180	-		0350													
017		1.1.6			1460	-		1140													
018		1.1.7		-	0815	-	-	0720													
019		1.1.8		-	0155	-	-	0610													
020		1.1.9		-	0255	-	-	0605													

D = DESCRIPTIVE INFORMATION
H = HEADING (FACTOR AND RESULT COLUMN HEADINGS)
S = SUBTOTAL DESIRED
T = TOTAL DESIRED
F = FACTOR DEVELOPMENT
LEAVE BLANK FOR CALCULATION CARDS

* { E = EXPONENT, +, −, ×, / }

$\pi = 3.14159$
$e = 2.71828$
TAN 30° = .577350
SIN 45° = .707107

RT TRIANGLE PROPORTIONS:
1:1:1.41421 1:4:4.12311
1:2:2.23607 1:5:5.09902
1:3:3.16226 1:6:6.08276

LENGTH OF ARC PER DEGREE FOR CIRCLE OF RADIUS 1 = .017453

VERIFY

NAME W. CHOW PHONE 140-207 DATE PAGE 1 OF 21

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Figure 25

6 FACTOR COMPUTATION

DIST.	GP.	BATCH	PAGE
19	6	10	01

LINE	TYPE	DATE MAY 12 66 DESCRIPTION	FACTOR A	OPERATION	FACTOR B	OPERATION	FACTOR C	OPERATION	FACTOR D	OPERATION	FACTOR E	OPERATION	FACTOR F	STORE DATA	RESULT
001	D		MATERIALS AND RESEARCH DEPARTMENT												
002	D		GAGE REDUCTION												
003	D		APPLE CANYON												
004	D		DATE 5 MAY 66												
005	D		FILL ELEVATION 2703												
006	D		CULVERT AIR TEMP. 61F												
007	D		REMARKS 67.9 FT. FILL OVER CROWN												
008	D		STRAIN GAGES												
009	D		STATION 7+25												
010	H		READING		ZERO										MICRO-INCHES
011	D	GAGE MEG IND. TIME													
012		111 1900	− 835	−	− 815										− 20.0000
013		112	− 950	−	− 345										− 605.0000
014		113	250	−	675										− 425.0000
015		114	730	−	560										170.0000
016		115	180	−	350										− 170.0000
017		116	1460	−	1140										320.0000
018		117	− 815	−	− 720										− 95.0000
019		118	− 155	−	− 610										455.0000
020		119	255	−	− 605										860.0000
021		1110	− 535	−	835										− 1,370.0000
022		1111	2090	−	1540										550.0000
023		121	570	−	770										− 200.0000
024		122	− 960	−	− 770										− 190.0000
025		123	2285	−	1045										1,240.0000
026		124	− 610	−	− 285										− 325.0000
027		125	130	−	225										− 95.0000
028		126	− 245	−	− 720										475.0000
029		127	100	−	590										− 490.0000
030		128	1580	−	1075										505.0000

OPERATIONS:
E = EXPONENT
+ = ADDITION
− = SUBTRACTION
X = MULTIPLICATION
/ = DIVISION

19	6	10	01
DIST.	GP.	BATCH	PAGE

Figure 26

STATE OF CALIFORNIA — HIGHWAY TRANSPORTATION AGENCY
DIVISION OF HIGHWAYS
COMPUTER SYSTEMS

6 FACTOR COMPUTATION

DIST	GROUP	BATCH
19	6	10

IN CASE OF ERROR RETURN DATA DO NOT CONTACT | CHECK

SOURCE DIST.	SOURCE UNIT	CHARGE DIST.	CHARGE UNIT	EXPENDITURE AUTHORIZATION (GEN. LED. / SUB-ACCT. / MAINT. W/O / ROUTE NO.) WORK ORDER NO.	PREFIX	SPECIAL DESIGNATION (USE WHEN APPLICABLE) BRIDGE NUMBERS / PARCEL OR CONTR. NO. / DWG. RPTS. LABR. / CDS., ENCR. PMTS. / SUB-JOB NOS. / LOCATIONS	OBJECT
19	605	19	605	762500	3	6360	142

LINE (6 7 8)	TYPE (9)	DESCRIPTION (10–27)	STORE DESC. (28 ±)	[(A (29–35)	* (36)	B) (37–43)	* (44)	C] (45–51)	* (52)	[(D (53–59)	* (60)	E) (61–67)	* (68)	F] (69–75)	STORE RESULT (76 77)
253	P					CULVERT									
254	D	← 20 →		DISPLACEMENT FIELD MEASUREMENTS											
255	D	← 34 →						STATION 7+25							
256	D	← 20 →		DATE 5 MAY 66											
257	D	← 20 →		TIME 1730											
258	D	← 20 →		TEMPERATURE 61°F											
259	H	←3→CHANGE INCHES		READING		INITIAL									
260	D	CØRD													
261		1		043.787	-	044.160									
262		2		076.946	-	077.374									
263		3		095.484	-	095.347									
264		4		100.851	-	100.051									
265		5		093.546	-	092.355									
266		6		072.555	-	072.411									
267		7		038.215	-	038.420									
268		8		038.186	-	038.374									
269		9		071.822	-	072.862									
270		10		092.324	-	092.730									
271		11		094.963	-	094.710									
272		12		076.819	-	077.165									

D = DESCRIPTIVE INFORMATION
H = HEADING (FACTOR AND RESULT COLUMN HEADINGS)
S = SUBTOTAL DESIRED
T = TOTAL DESIRED
F = FACTOR DEVELOPMENT
LEAVE BLANK FOR CALCULATION CARDS

* E = EXPONENT, +, −, x, /

π = 3.14159
e = 2.71828
TAN 30° = .577350
SIN 45° = .707107

RT TRIANGLE PROPORTIONS:
1:1:1.41421   1:4:4.12311
1:2:2.23607   1:5:5.09902
1:3:3.16228   1:6:6.08276

LENGTH OF ARC PER DEGREE FOR CIRCLE OF RADIUS 1=.017453

VERIFY

WH-67A5 (Rev.-7-64)

NAME W. CHOW   PHONE 140-207   DATE

PAGE 18 OF 21

Figure 27

6 FACTOR COMPUTATION

LINE	TYPE	DATE: MAY 12 66 / DESCRIPTION	FACTOR A	OPERATION	FACTOR B	OPERATION	FACTOR C	OPERATION	FACTOR D	OPERATION	FACTOR E	OPERATION	FACTOR F	STORE DATA	RESULT (DIST. 19, GP. 6, BATCH 10, PAGE 16)
253	P				CULVERT										
254	D		DISPLACEMENT FIELD MEASUREMENTS												
255	D				STATION 7+25										
256	D		DATE 5 MAY 66												
257	D		TIME 1730												
258	D		TEMPERATURE 61F												
259	H		READING		INITIAL										CHANGE INCHES
260	D	CORD													
261		1	43.787	-	44.160										- .3730
262		2	76.946	-	77.374										- .4280
263		3	95.484	-	95.347										.1370
264		4	100.851	-	100.051										.8000
265		5	93.546	-	92.355										1.1910
266		6	72.555	-	72.411										.1440
267		7	38.215	-	38.420										- .2050
268		8	38.186	-	38.374										- .1880
269		9	71.822	-	72.862										- 1.0400
270		10	92.324	-	92.730										- .4060
271		11	94.963	-	94.710										.2530
272		12	76.819	-	77.165										- .3460
273		13	43.974	-	44.153										- .1790
274		14	110.210	-	112.075										- 1.8650

OPERATIONS:
E = EXPONENT
+ = ADDITION
− = SUBTRACTION
X = MULTIPLICATION
/ = DIVISION

DIST.	GP.	BATCH	PAGE
19	6	10	16

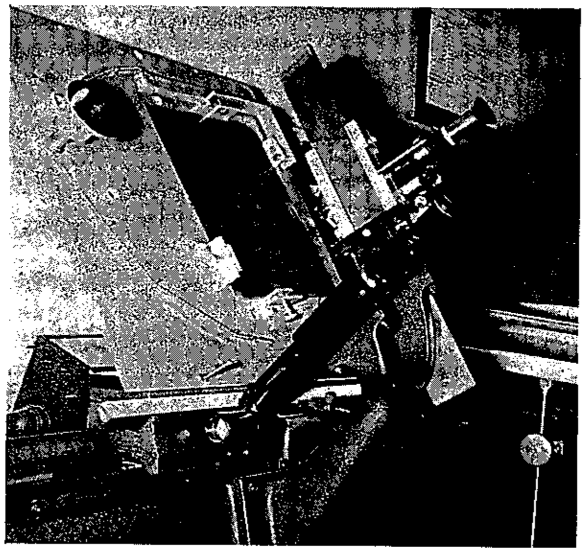


FIGURE 28
GAERTNER COMPARATOR

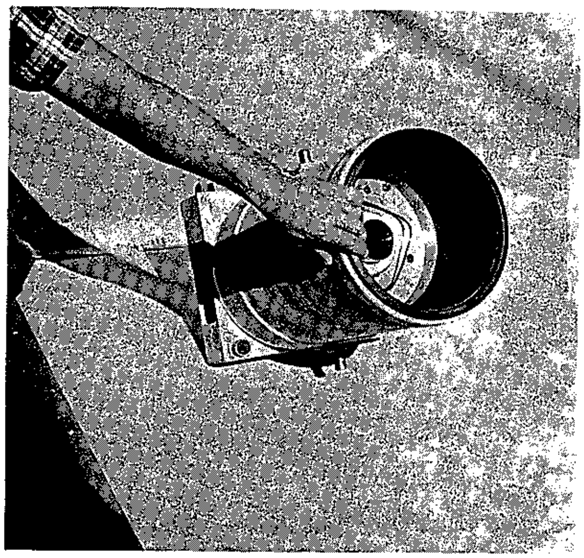
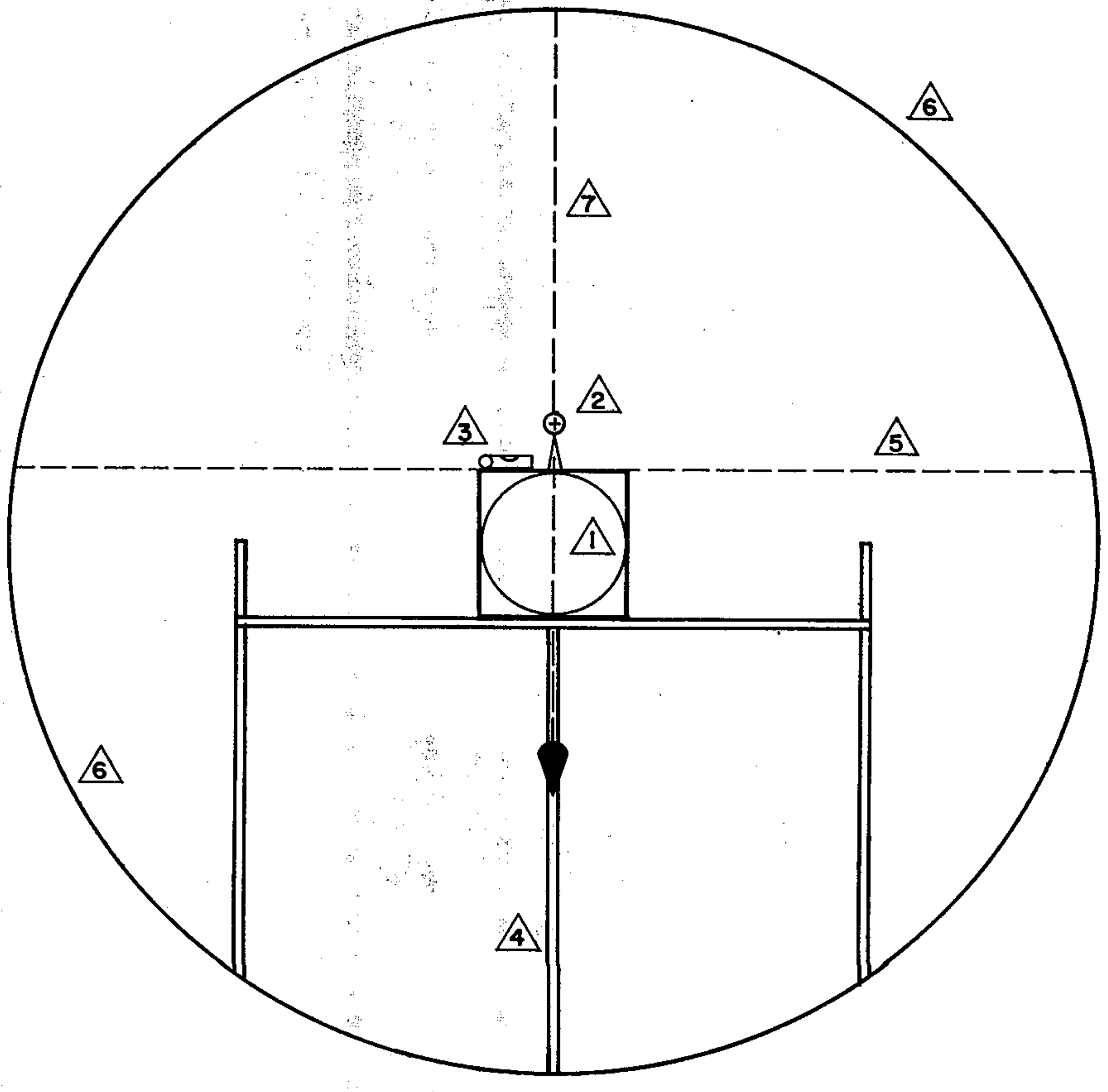


FIGURE 29
K-37 CAMERA

Figure 30

CULVERT DISPLACEMENT FIELD MEASUREMENT

View of Photographic Camera Setup

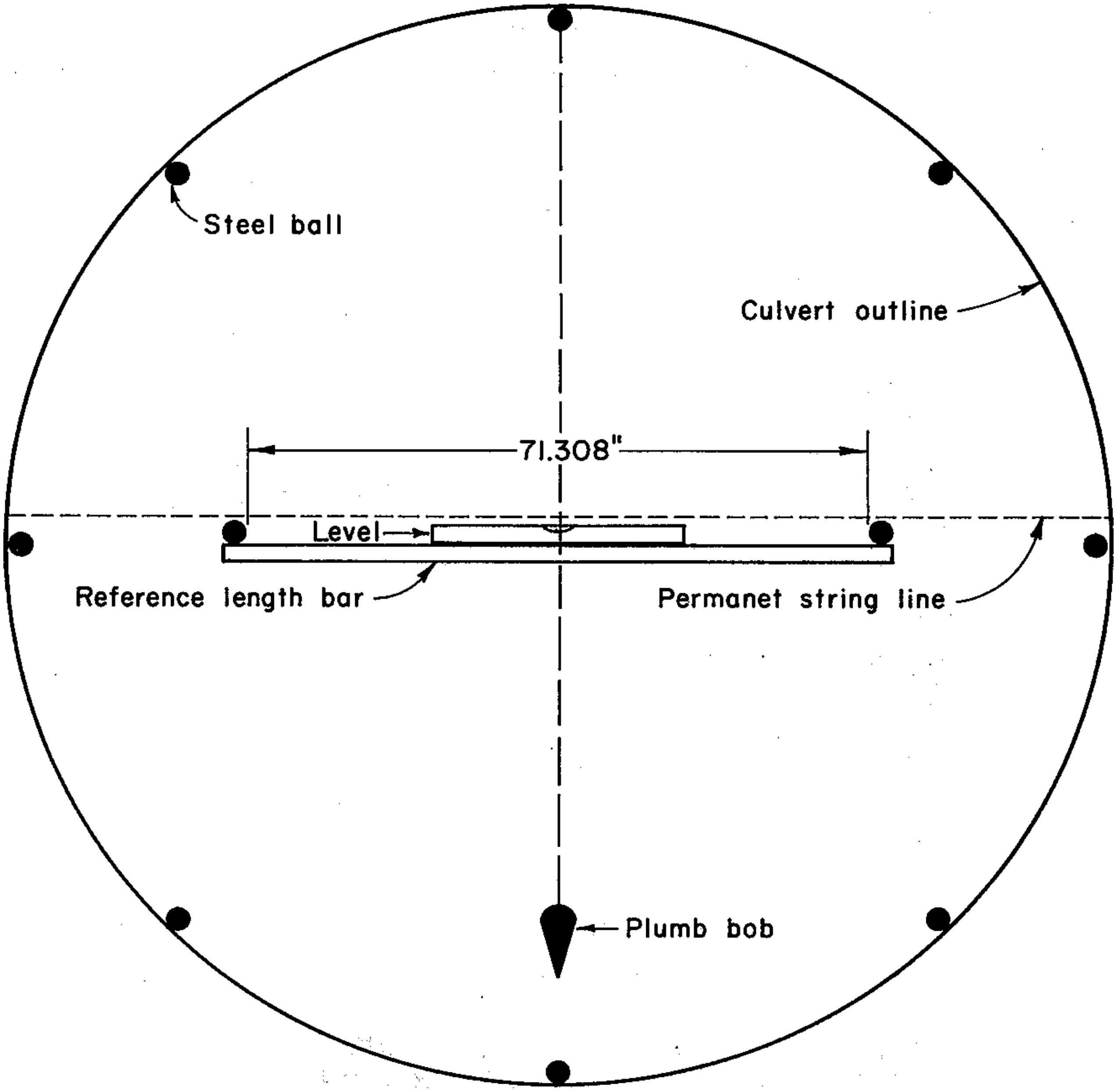


1. Aircraft reconnassance camera Gordon K-37
2. 7 power telescope finder
3. Starrett #136 cross test level
4. Tubular tripod camera mounting frame
5. Reference string line
6. Culvert outline
7. Vertical plumb line

No Scale

CULVERT DISPLACEMENT FIELD MEASUREMENT

Photographic Method – Camera view of the 8 steel balls and the reference length bar.



Note:

Level: 0.0005"/foot/division sensitivity
Reference length bar leveled to one division on the level

No Scale

FIGURE 34

APPLE CANYON

Sta. 7 + 25

Chord Lengths vs. Fill Height

Batch	Fill Over Crown, Ft.	Chord #14 Length, in. Photo.	Differential Chord Length, in.	Chord #14 Length, in. Micrometer	Differential Chord Length, in.	Batch	Fill Over Crown, Ft.	Chord #1 Length, in. Photo.	Differential Chord Length, in.	Chord #1 Length, in. Micrometer	Differential Chord Length, in.
3	39	111.029		111.110		3	39	43.948		43.922	
			.259		.270				.104		.032
4	52	110.770		110.840		4	52	43.844		43.890	
			.148		.196				.026		.036
5	68	110.623		110.644		5	68	43.818		43.854	
			.148		.164				.047		.025
6	68	110.475		110.480		6	68	43.771		43.829	
			.305		.100				.101		.019
7	68	110.170		110.380		7	68	43.771		43.810	
			-.203		.085				-.102		.010
8	68	110.373		110.295		8	68	43.772		43.800	
			.275		.070				.085		.015
9	68	110.098		110.215		9	68	43.687		43.785	
			.077		.005				.028		-.002
10	68	110.021		110.210		10	68	43.659		43.787	

APPLE CANYON CULVERT

Sta. 7 + 25

Frequency distribution of the differences between the photographic and the inside micrometer chord length measurements. Data are from batches #3 through #10 inclusive. Units are in 0.001" increments.

	UNITS (0.001")				
Shorter than micrometer	326 - 350	111			
	301 - 325	11			
	276 - 300				
	251 - 275	1			
	226 - 250	1111			
	201 - 225	11111			
	176 - 200	11111	1		
	151 - 175	11111	11		
	126 - 150	11111	11111	11	
	101 - 125	11111	11		
	76 - 100	11111	11111	11111	1
	51 - 75	11111	11111	1111	
	26 - 50	11111	11111	11111	11111
	0 - 25	11111	11111	11111	1
Longer than micrometer	0 - 25	11111	11111	11111	1111
	26 - 50	11111	11111	1111	
	51 - 75	11111	11111	11	
	76 - 100	11111	11111	11111	1111
	101 - 125	11111	11111	11	
	126 - 150	11111	11		
	151 - 175	11111			
	176 - 200	11111			
	201 - 225				
	226 - 250	1			
	251 - 275				
	276 - 300				
	301 - 325				
	326 - 350	1			

N = 206

$\overline{X}$ = .092"

σ = .060"

Figure 36

DIST	GROUP	BATCH
1 9	6	1 0
IN CASE OF ERROR RETURN DATA DO NOT CONTACT		CHECK

STATE OF CALIFORNIA – HIGHWAY TRANSPORTATION AGENCY
DIVISION OF HIGHWAYS
COMPUTER SYSTEMS

6 FACTOR COMPUTATION

SOURCE DIST.	SOURCE UNIT	CHARGE DIST.	CHARGE UNIT	EXPENDITURE AUTHORIZATION (GEN. LED. / SUB-ACCT.; MAINT. W/O / ROUTE NO.) WORK ORDER NO.	SPECIAL DESIGNATION (USE WHEN APPLICABLE) PREFIX / BRIDGE NUMBERS / PARCEL OR CONTR. NO. / DWG. RPTS. LABR. / CDS., ENCR. PMTS. / SUB-JOB NOS. / LOCATIONS	OBJECT
19	605	19	605	762500	36360	142

LINE (6 7 8)	TYPE (9)	DESCRIPTION (10–27)	STORE DESC (28)	[(A (29–35)	* (36)	B) (37–43)	* (44)	C] (45–51)	* (52)	[(D (53–59)	* (60)	E) (61–67)	* (68)	F] (69–75)	STORE RESULT (76 77)
		CØRD		READING		INITIAL									
273		13		043.974	-	044.153									
274		14		110.210		112.075									
275	P					CULVERT									
276	D	← 20 →		LONGITUDINAL MEASUREMENTS											
277	D	← 20 →		DATE 5 MAY 66											
278	D	← 20 →		TIME 1845											
279	D	← 20 →		TEMPERATURE 55°F											
280	H	← 3 → CHANGE INCHES		READING		INITIAL									
281	D	PØSITIØN													
282		1		012.899	-	012.871									
283		2		012.708	-	012.645									
284		3		012.764	-	012.801									
285		4		012.853	-	012.843									

D = DESCRIPTIVE INFORMATION
H = HEADING (FACTOR AND RESULT COLUMN HEADINGS)
S = SUBTOTAL DESIRED
T = TOTAL DESIRED
F = FACTOR DEVELOPMENT
LEAVE BLANK FOR CALCULATION CARDS

* = { E = EXPONENT, +, –, ×, / }

π = 3.14159
e = 2.71828
TAN 30° = .577350
SIN 45° = .707107

RT TRIANGLE PROPORTIONS:
1:1:1.41421 1:4:4.12311
1:2:2.23607 1:5:5.09902
1:3:3.16228 1:6:6.08276

LENGTH OF ARC PER DEGREE FOR CIRCLE OF RADIUS 1=.017453

VERIFY

WH-67A5 (Rev.-7-64)

NAME W. CHOW PHONE 140-207 DATE

PAGE 19 OF 21

Figure 37

6 FACTOR COMPUTATION

DATE: MAY 12 66

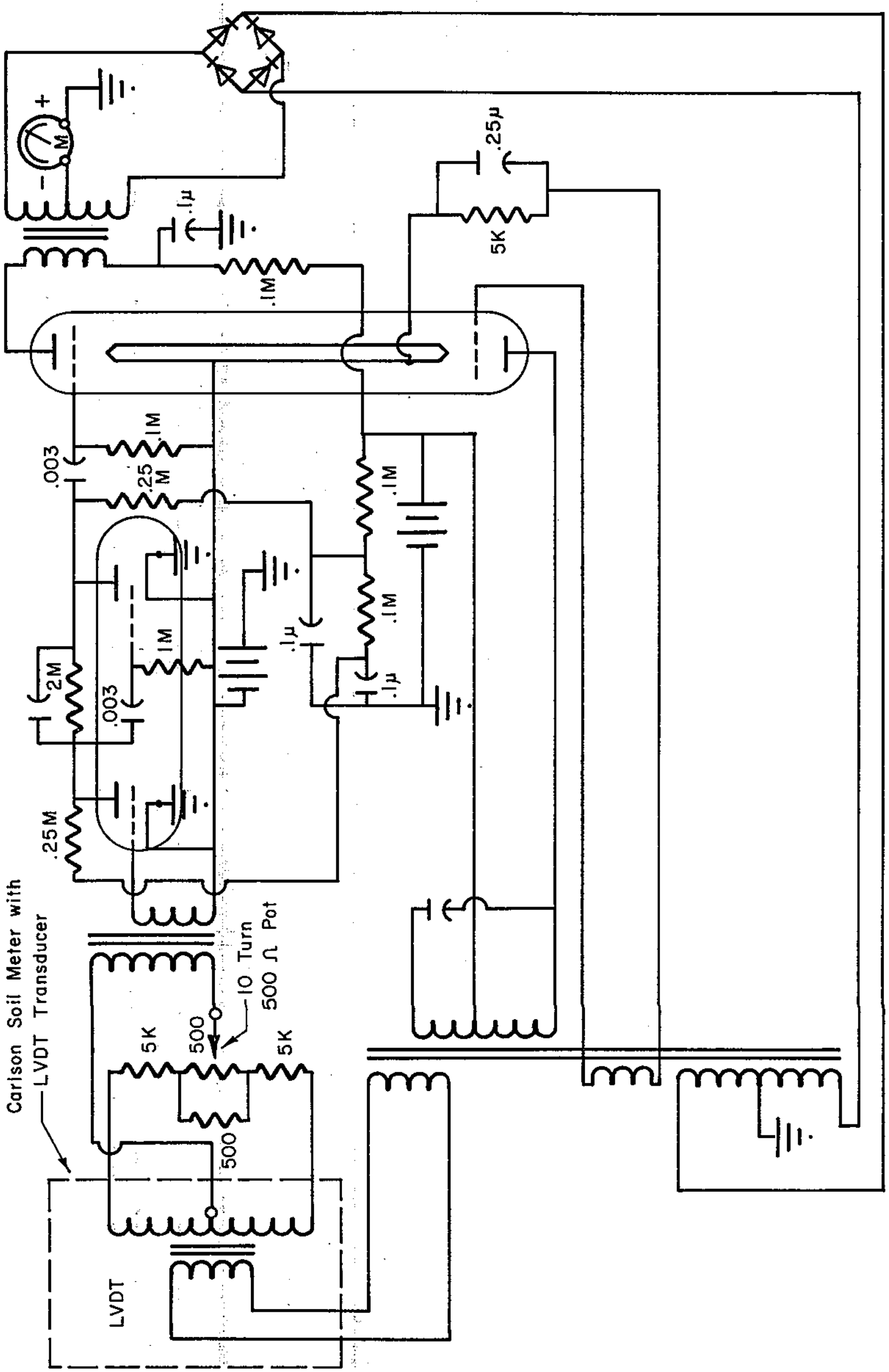
DIST.	GP.	BATCH	PAGE
19	6	10	17

LINE	TYPE	DESCRIPTION	FACTOR A	OPERATION	FACTOR B	OPERATION	FACTOR C	OPERATION	FACTOR D	OPERATION	FACTOR E	OPERATION	FACTOR F	STORE DATA	RESULT
275	P				CULVERT										
276	D		LONGITUDINAL MEASURMENTS												
277	D		DATE 5 MAY 66												
278	D		TIME 1845												
279	D		TEMPERATURE 55F												
280	H		READING		INITIAL										CHANGE INCHES
281	D	POSITION													
282		1	12.899	-	12.871										.0280
283		2	12.708	-	12.645										.0630
284		3	12.764	-	12.801										- .0370
285		4	12.853	-	12.843										.0100

DIST.	GP.	BATCH	PAGE
19	6	10	17

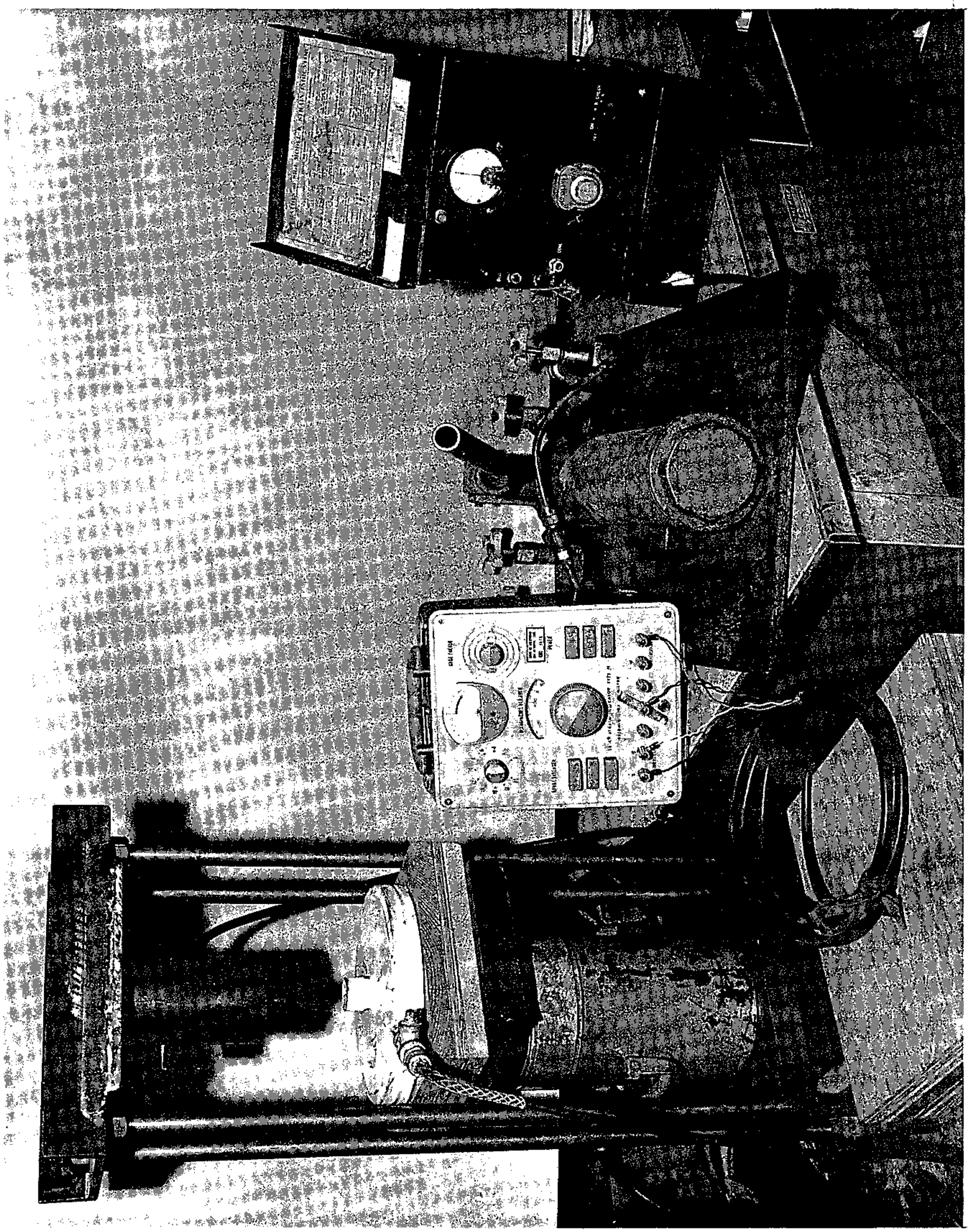
OPERATIONS:
E = EXPONENT
+ = ADDITION
- = SUBTRACTION
X = MULTIPLICATION
/ = DIVISION

Figure 38



WIRING DIAGRAM OF MODIFIED BALDWIN TYPE K INDICATOR FOR READING MODIFIED CARLSON SOIL METER WITH LVDT TRANSDUCER

FIGURE 39



SOIL PRESSURE METER CALIBRATION SETUP

FIGURE 40

SOIL PRESSURE METER CALIBRATION

Apple Canyon

100 psi Capacity

Date: October 19, 1965 Cell Number 1 Indicator: 8

Load Lbs.	Baldwin Indicator Reading							
	Trial 1	Diff.	Trial 2	Diff.	Trial 3	Diff.	Ave. Diff.	Sub-Total Diff.
0	305		306		306			0
500	330	25	332	26	332	26	26	26
1000	356	26	358	26	358	26	26	52
1500	383	27	384	26	385	27	27	79
2000	410	27	412	28	412	27	27	106
3000	467	57	469	57	469	57	57	163
4000	525	58	527	58	528	59	58	221
5000	584	59	585	58	586	58	58	279
6000	644	60	644	59	645	59	59	338
0	306		306					

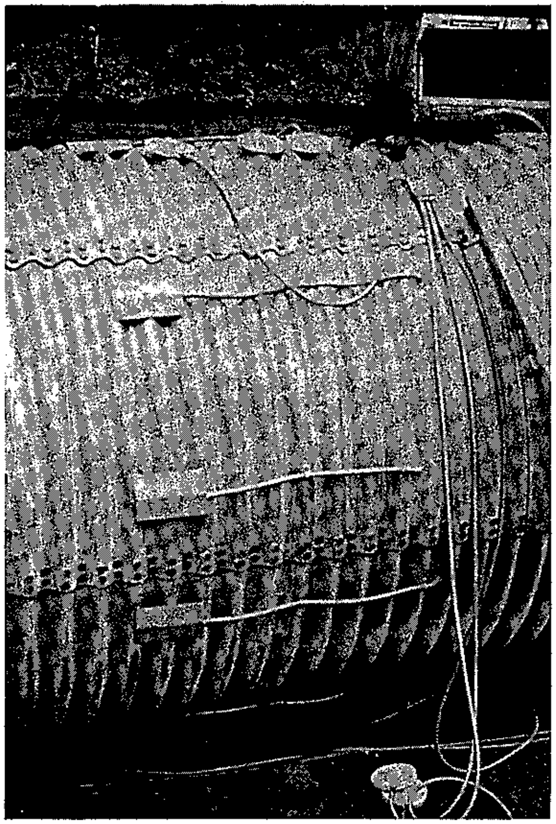


FIGURE 41

VIEW OF THREE SOIL METERS ON TOP
OF THE PIPE AND TWO ON THE GROUND

FIGURE 42

SOIL METER INSTALLATION PRIOR TO
BACKFILLING.

Figure 43

DIST	GROUP	BATCH
19	6	10

IN CASE OF ERROR RETURN DATA DO NOT CONTACT | CHECK

STATE OF CALIFORNIA — HIGHWAY TRANSPORTATION AGENCY
DIVISION OF HIGHWAYS
COMPUTER SYSTEMS

6 FACTOR COMPUTATION

SOURCE DIST.	SOURCE UNIT	CHARGE DIST.	CHARGE UNIT	EXPENDITURE AUTHORIZATION (GEN. LED. / SUB-ACCT.; MAINT. W/O / ROUTE NO.; WORK ORDER NO.)	SPECIAL DESIGNATION (USE WHEN APPLICABLE) PREFIX / BRIDGE NUMBERS / PARCEL OR CONTR. NO. / DWG. RPTS. LABR. / CDS., ENCR. PMTS. / SUB-JOB NOS. / LOCATIONS	OBJECT
19	605	19	605	762500	36360	142

LINE 5 7 8	TYPE 9	DESCRIPTION 10–27	STORE DESC 28	±	[(A 29–35	* 36	±	B) 37–43	* 44	±	C] 45–51	* 52	±	[(D 53–59	* 60	±	E) 61–67	* 68	±	F] 69–75	STORE RESULT 76 77
191	P				SØIL			PRES.			METERS										
192		← 20 →			STATION			7+25 ← 6 →			TIME 5			MAY 6619			15				
193		← 4 → PRESSURE PSI			READING			ZERØ			FACTOR										
194		GAGE NO. MEG. IND.																			
195		001-511			440	-		256	X		.303										
196		002-512			339	-		126	X		.284										
197		003-513			543	-		473	X		.260										
198		004-514			352	-		184	X		.281										
199		005-515			399	-		220	X		.259										
200		006-516			423	-		343	X		.255										
201		007-517-0600			465	-		180	X		.273										
202		008-518			646	-		442	X		.269										
203		009-519			297	-		154	X		.214										
204		010-5110			495	-		290	X		.278										
205		011-521			456	-		294	X		.284										
206		012-522			481	-		312	X		.245										
207		013			430	-		320	X		.263										
208		014			397	-		254	X		.273										
209		015			336	-		212	X		.272										

D = DESCRIPTIVE INFORMATION
H = HEADING (FACTOR AND RESULT COLUMN HEADINGS)
S = SUBTOTAL DESIRED
T = TOTAL DESIRED
F = FACTOR DEVELOPMENT
LEAVE BLANK FOR CALCULATION CARDS

* { E = EXPONENT, +, −, x, / }

π = 3.14159
e = 2.71828
TAN 30° = .577350
SIN 45° = .707107

RT TRIANGLE PROPORTIONS:
1:1:1.41421 1:4:4.12311
1:2:2.23607 1:5:5.09902
1:3:3.16226 1:6:6.08276

LENGTH OF ARC PER DEGREE FOR CIRCLE OF RADIUS 1=.017453

VERIFY

NAME W. CHOW PHONE 140-207 DATE

WH-67A5 (Rev.-7-64)

FIGURE 44

6 FACTOR COMPUTATION

DIST.	GP.	BATCH	PAGE
19	6	10	11

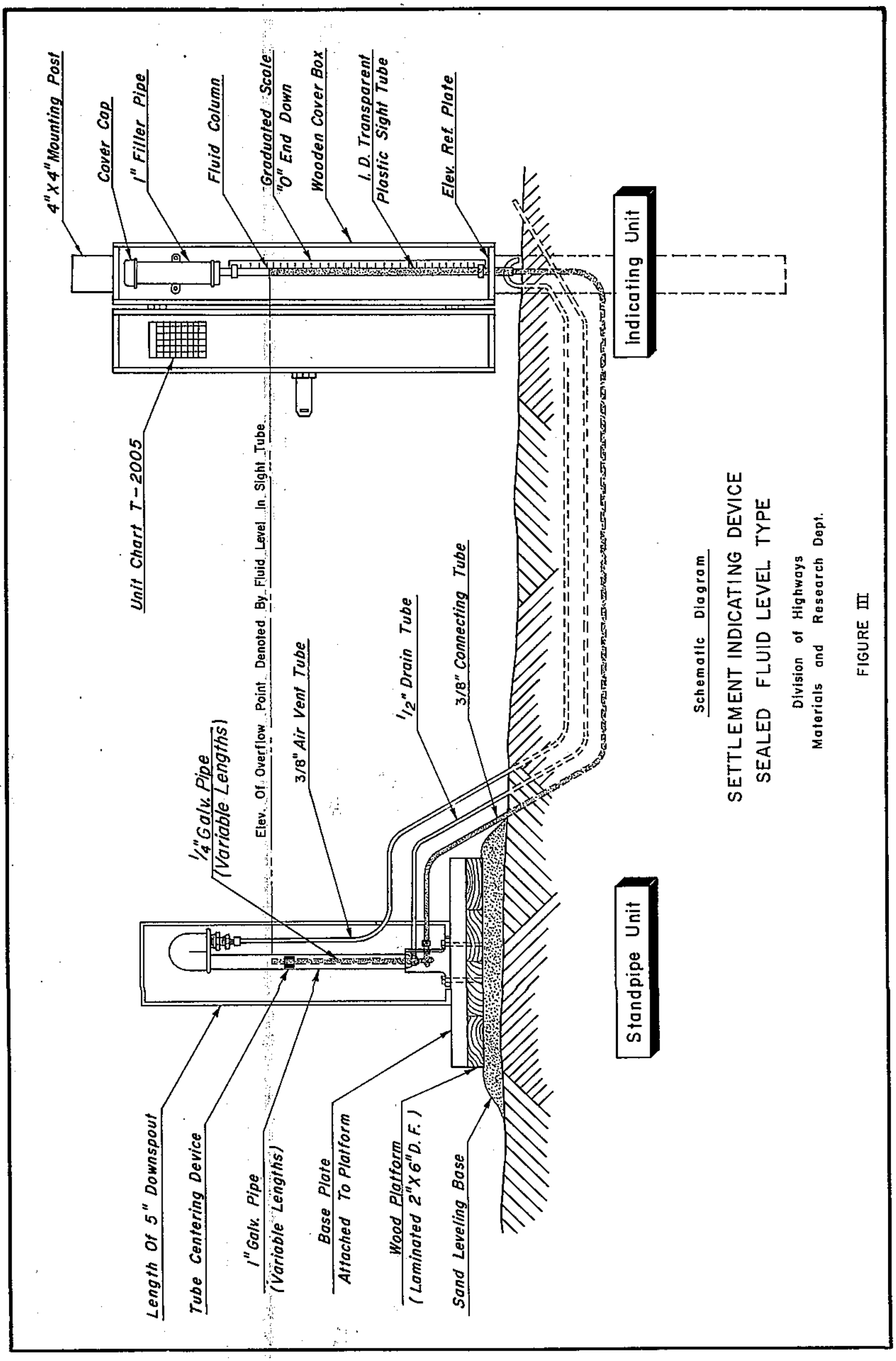
DATE: MAY 12 66

LINE	TYPE	DESCRIPTION	[(FACTOR A	OPERATION	FACTOR B)	OPERATION	FACTOR C]	OPERATION	[(FACTOR D	OPERATION	FACTOR E)	OPERATION	FACTOR F]	STORE DATA	RESULT
191	P		SOIL		PRES.		METERS								
192	D		STATION 7+25				TIME 5 MAY 66		1915						
193	H		READING		ZERO		FACTOR								PRESSURE PSI
194	D	GAGE NO. MEG IND													
195		001-511	440	-	256	X	.303								55.7520
196		002-512	339	-	126	X	.284								60.4920
197		003-513	543	-	473	X	.260								18.2000
198		004-514	352	-	184	X	.281								47.2080
199		005-515	399	-	220	X	.259								46.3610
200		006-516	423	-	343	X	.255								20.4000
201		007-517 0600	465	-	180	X	.273								77.8050
202		008-518	646	-	442	X	.269								54.8760
203		009-519	297	-	154	X	.214								30.6020
204		010-5110	495	-	290	X	.278								56.9900
205		011-521	456	-	294	X	.284								46.0080
206		012-522	481	-	312	X	.245								41.4050
207		013	430	-	320	X	.263								28.9300
208		014	397	-	254	X	.273								39.0390
209		015	336	-	212	X	.272								33.7280

OPERATIONS:
E = EXPONENT
+ = ADDITION
− = SUBTRACTION
X = MULTIPLICATION
/ = DIVISION

19	6	10	11
DIST.	GP.	BATCH	PAGE

Figure 45


4"X4" Mounting Post
Cover Cap
1" Filler Pipe
Fluid Column
Graduated Scale
"0" End Down
Wooden Cover Box
I. D. Transparent
Plastic Sight Tube
Elev. Ref. Plate
Indicating Unit
Unit Chart T-2005
Elev. Of Overflow Point Denoted By Fluid Level In Sight Tube
1/4" Galv. Pipe
(Variable Lengths)
3/8" Air Vent Tube
1/2" Drain Tube
3/8" Connecting Tube
Standpipe Unit
Length Of 5" Downspout
Tube Centering Device
1" Galv. Pipe
(Variable Lengths)
Base Plate
Attached To Platform
Wood Platform
(Laminated 2"X6" D.F.)
Sand Leveling Base
Schematic Diagram
SETTLEMENT INDICATING DEVICE
SEALED FLUID LEVEL TYPE
Division of Highways
Materials and Research Dept.
FIGURE III

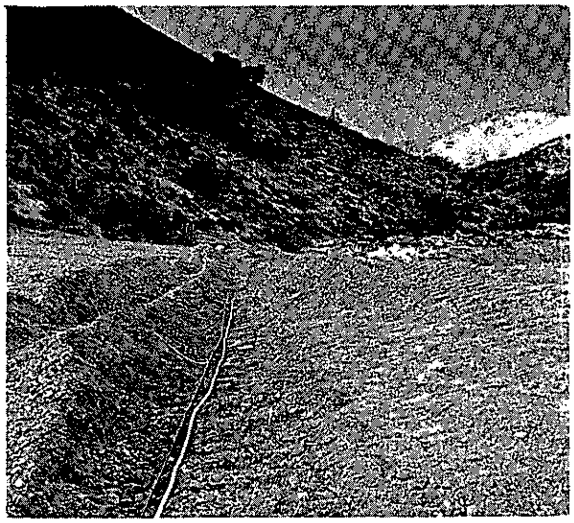


FIGURE 46
SETTLEMENT PLATFORM LINES

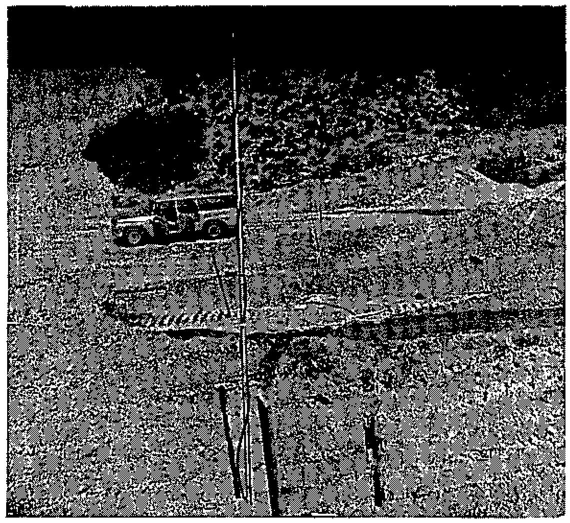


FIGURE 47
SETTLEMENT PLATFORM #40

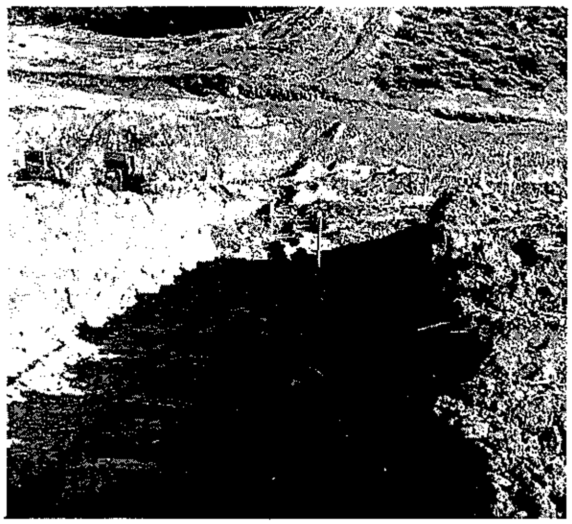
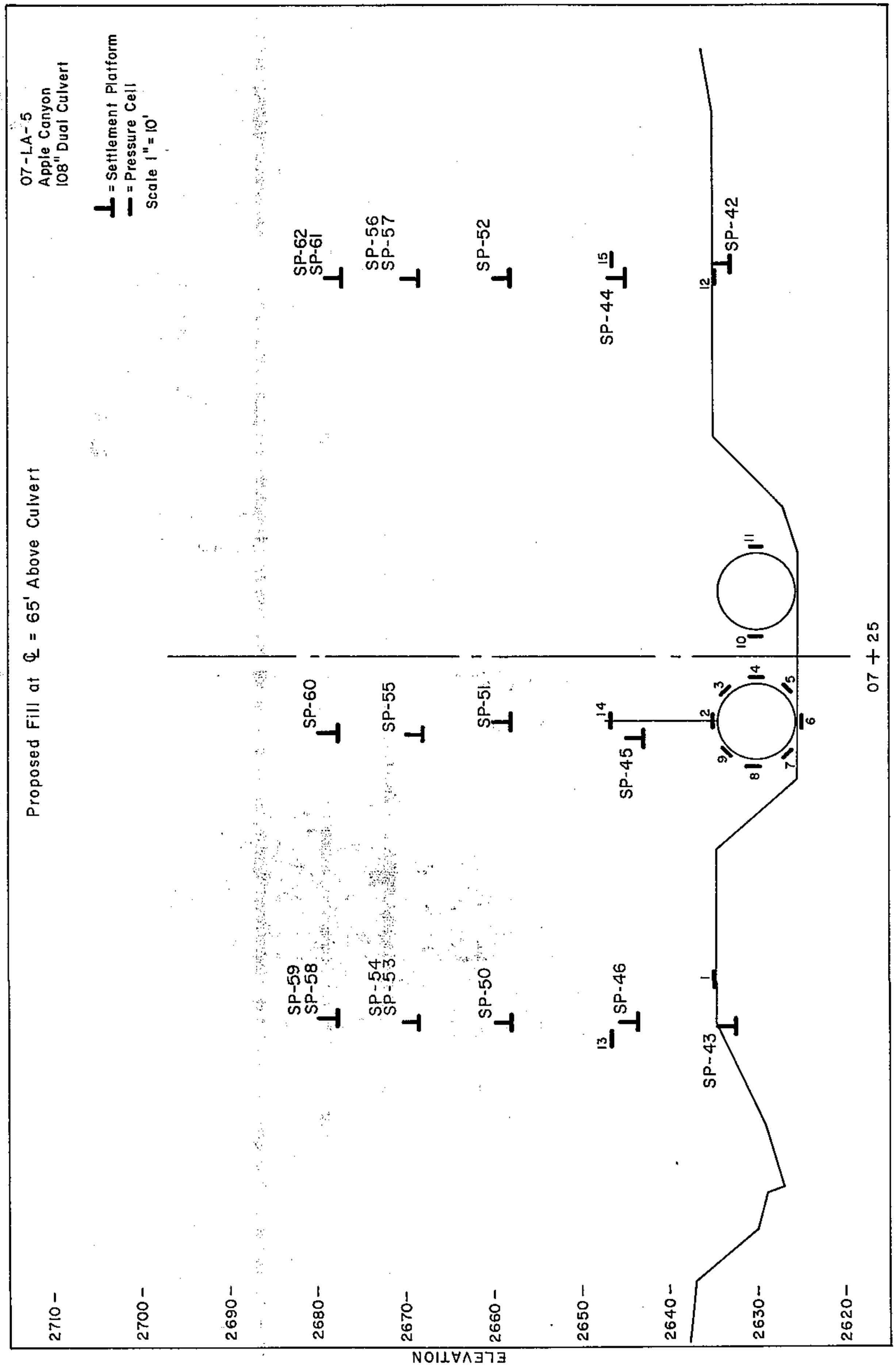


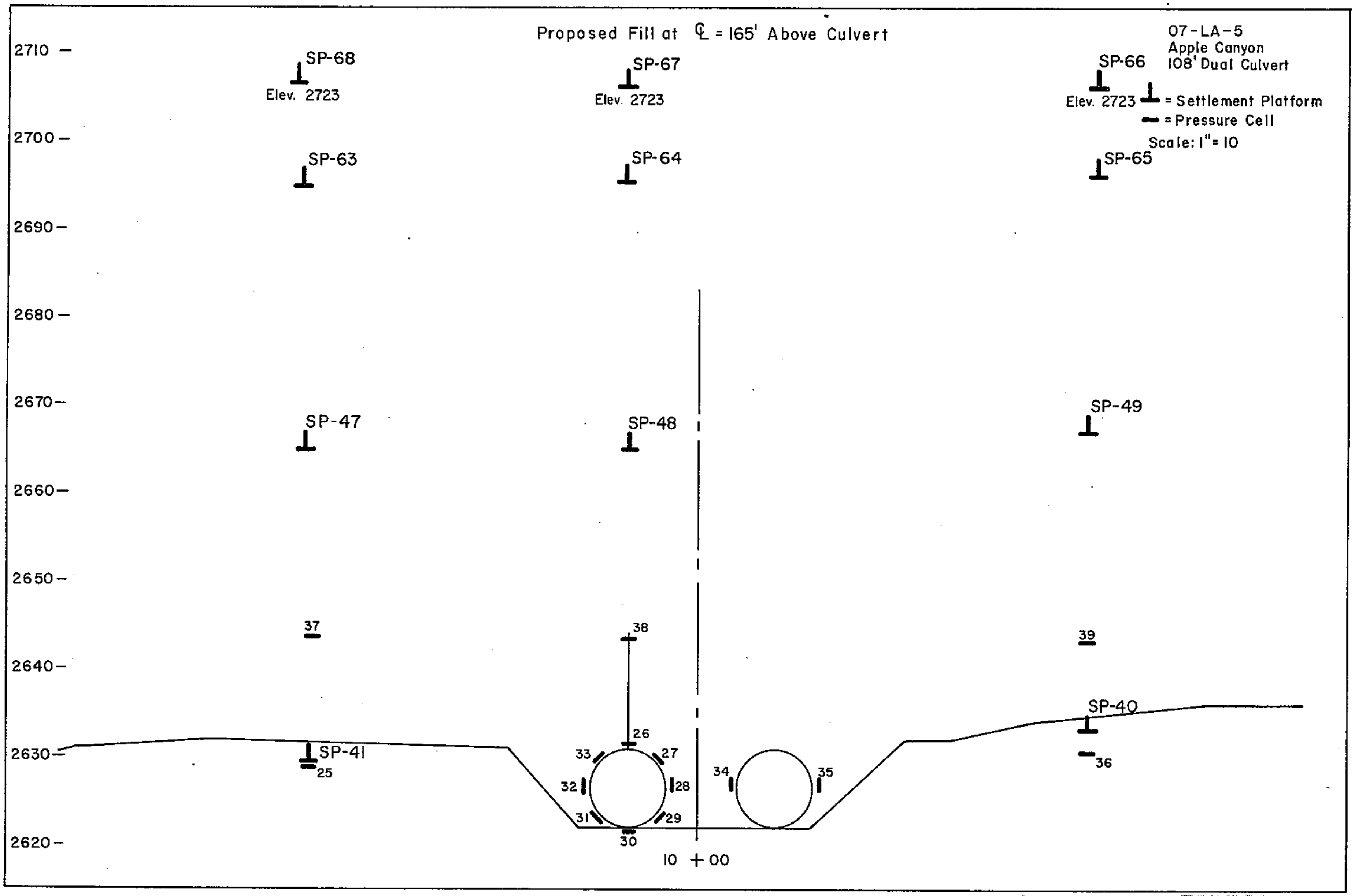
FIGURE 48
SETTLEMENT PLATFORM #42

Figure 49



07-LA-5
Apple Canyon
108" Dual Culvert
= Settlement Platform
= Pressure Cell
Scale 1" = 10'
Proposed Fill at ℄ = 65' Above Culvert
SP-62
SP-61
SP-56
SP-57
SP-52
SP-44
SP-42
SP-60
SP-55
SP-51
SP-45
SP-59
SP-58
SP-54
SP-53
SP-50
SP-46
SP-43
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
07 + 25
2710
2700
2690
2680
2670
2660
2650
2640
2630
2620
ELEVATION

Figure 50



Proposed Fill at ℄ = 165' Above Culvert
07-LA-5
Apple Canyon
108' Dual Culvert
= Settlement Platform
= Pressure Cell
Scale: 1" = 10
2710
2700
2690
2680
2670
2660
2650
2640
2630
2620
SP-68
Elev. 2723
SP-67
Elev. 2723
SP-66
Elev. 2723
SP-63
SP-64
SP-65
SP-47
SP-48
SP-49
37
38
39
SP-40
36
SP-41
25
26
27
28
29
30
31
32
33
34
35
10 + 00

Figure 51

TO HEADQUARTERS LABORATORY

STATE OF CALIFORNIA - DEPARTMENT OF PUBLIC WORKS
DIVISION OF HIGHWAYS
Materials & Research Department

SETTLEMENT DATA
FORM T-2006 (REV. 3-57)

JOB NO.	DATE	PAGE
624111	8/12/66	1 of 2

DIST.	CO.	RTE.	SEC.
07	LA	5	PM

CONTRACT	LOCATION
Kirst	Apple Canyon

NUMBER OR STATION	WATER TUBE READING	REFERENCE NAIL ELEVATION	RISER PIPE: ELEVATION TOP OF PIPE	RISER PIPE: LENGTH OF PIPE	SETTLEMENT PLATFORM: ORIGINAL ELEVATION	SETTLEMENT PLATFORM: PRESENT ELEVATION	SETTLEMENT IN FEET	FILL HEIGHT: SURFACE ELEVATION	FILL HEIGHT: FILL ABOVE ORIGINAL GROUND	ELAPSED TIME DAYS	UNIT WEIGHT OF FILL LB/CU. FT. REMARKS
S.P. #40	1.38	2636.54	2637.92	9.41	2631.01	2628.51	2.50			153	
41	1.22	2635.36	2636.58	9.38	2629.63	2627.20	2.43				
42	1.44	2634.84	2636.28	4.42	2632.85	2631.86	0.99				
43	1.28	2634.82	2636.10	4.42	2632.47	2631.68	0.79				
44	0.51	2647.99	2648.50	4.44	2645.17	2644.06	1.11				
45	0.43	2645.93	2646.36	4.44	2643.00	2641.92	1.08				
46	0.25	2646.67	2646.92	4.43	2643.50	2642.49	1.01				
47	0.95	2663.23	2664.18	2.60	2664.50	2661.58	2.92				
48	1.17	2663.56	2664.73	2.58	2665.11	2662.15	2.96				
49	0.36	2666.19	2666.55	2.57	2666.69	2663.98	2.71				
50	1.48	2659.91	2661.39	3.58	2658.30	2657.81	0.49				
51	1.16	2659.85	2661.01	3.59	2658.24	2657.42	0.82				
52	0.80	2660.14	2660.94	3.59	2658.43	2657.35	1.07				
53	1.36	2668.95	2670.31	2.67	2668.40	2667.64	0.76				
54	1.63	2668.50	2670.13	2.67	2668.03	2667.46	0.57				
55	0.98	2668.90	2669.88	2.65	2667.99	2667.23	0.76				
56	1.52	2668.67	2670.19	2.61	2668.36	2667.58	0.78				
57	1.17	2668.65	2669.82	2.62	2667.89	2667.20	0.69				
58	1.23	2679.31	2680.54	2.69	2678.57	2677.85	0.72				
59	1.51	2679.61	2680.12	2.56	2679.13	2677.56	0.57				
60	1.08	2679.44	2680.52	2.63	2678.73	2677.89	0.84				
61	1.10	2678.85	2679.95	2.69	2678.14	2677.26	0.88				
62	1.18	2679.32	2680.50	2.64	2678.79	2677.86	0.93				

UARCO INC. - OAKLAND 85310

Figure 52

TIME-SETTLEMENT GRAPHS OF SETTLEMENT DEVICES
GROUPED BY VERTICAL COLUMN
DUAL 108" D. CULVERT APPLE CANYON STA. 7+25